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THE

PRACTICAL EXAMINATOR

ON

Steam and the Steam Engine:

WITH

INSTRUCTIVE REFERENCES RELATIVE THERETO.

ARRANGED FOR THE USE OF

Engineers, Students, and Others.

By WILLIAM TEMPLETON,
ENGINEER.

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PREFACE.

THE following pages were not originally written with a view to publication, but merely intended as a private means, simple and concise, by which to impress upon the author's mind necessary available facts relative to steam and the steam-engine.

Promiscuously, however, in support of assertion educed by argument, in company of engineers, the manuscript was appealed to, the consequence of which was an eager expression of belief that, seeing the benefits to myself, the work might be equally useful to them and others, provided it were submitted to publication. To this I felt exceedingly reluctant, because of the peculiar mode I had selected for individual purpose. My reluctance, however, was ultimately overcome by the consideration

of the possible utility of the work to practical men entering either the naval or the commercial service as engineers, for which appointments a competent knowledge of steam and the steam-engine is, by examination, now imperatively required.

Having thus far explained my reasons for writing, and also for publication, I have only further to add, that the matter, although not altogether original, yet, in its simplified and condensed form, for constant and immediate application, will be to many of more real value as a text-book and ready prompter, which practical emergencies so frequently require, than a more elaborate work, increased in magnitude by elementary research.

The first edition was sold off in an incredibly short space of time, and a second edition solicited, with augmentations for more general purposes; in compliance with which demand I have carefully revised the whole, and made considerable additions, so

as to render the work more generally useful to the practical engineer, by assisting the memory in matters relating to steam-engines for land purposes or marine navigation, and also by affording valuable information to students of other classes, who have to acquire a similar knowledge by command or otherwise.

The utility of the work is also much enhanced by the addition of enlarged tables of various descriptions for practical reference, by which time in calculation is saved, and uncertainty much diminished; hence the work will be found to comprehend numerous rules, practical observations, and tables of merit, arranged in the most explicit form that individual ingenuity could studiously devise.

LONDON, *August*, 1852.

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PRACTICAL EXAMINATOR

ON

STEAM AND THE STEAM-ENGINE.

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1. *What amount of elementary knowledge, independent of practical qualifications, is necessary to constitute an individual a practical engineer?*

In the construction or practical working of a steam-engine, the elementary requirements are diversified; but the most necessitous are a knowledge of the properties of steam, and the principles of the steam-engine relative thereto.

2. *What is steam?*

Steam, generally, is the aqueous vapour arising from water at any degree of temperature; but steam, available as a motive power, is the vapour produced from water when heated to 212° Fah. and upwards.

3. *Why designate steam an aqueous vapour?*

First, because it is produced from *aqua*, or water, combined with heat; and second, in order to distinguish it from that of a gas: the properties of the latter being those of retaining permanently the aeriform state, unless liquefied by compression; while the aeriform state of the former cannot be retained unless at a uniform temperature, and in contact with the water from which it was generated.

4. *What are degrees of temperature?*

By degrees of temperature is understood the quantity of sensible heat in steam, water, air, &c., as indicated by the expansion or rise of the mercury in the tube of a thermometer.

5. *What is a thermometer?*

An instrument founded on the properties which heat possesses of expanding all bodies, the degrees of temperature being measured by the contractions and expansions of a column of mercury, the heat of boiling and freezing water being regarded as two fixed points, and the space between them divided into a certain number of equal parts.

Fahrenheit's scale; the freezing point of fresh water is 32°, and the boiling point 212°.

6. *Is steam, and the water from which it is generated, of equal temperatures while they remain in immediate contact?*

Yes; and under such circumstances designated common steam, and of low pressure if not exceeding fifteen pounds per square inch above that of atmospheric pressure; or high-pressure steam when exceeding that density.

7. *Why make the distinction common steam?*

Because, when steam is separated by another vessel from its water of formation, it may be subjected to a greater degree of heat, whereby the watery particles of which it is composed are diminished in bulk, but augmented in quantity and elastic force, through excess of caloric, and commonly termed superheated steam.

8. *What is meant by steam being available as a motive power?*

Steam being available as a motive power, signifies that its inherent force or power is so great as to cause useful motion to machinery through the medium of the steam-engine.

9. *What are the inherent qualities of steam?*

Elasticity, Expansibility, and Latent or Concealed Heat.

10. *What is meant by elasticity?*

Elasticity of steam is the power which it has in itself of returning to its original form, after being made to deviate by some external force; the force which it exerts in endeavouring to recover its position being the measure of its elasticity.

11. *How is the amount of elastic force of steam obtained by calculation?*

Rule:—To the indicated temperature of the steam in degrees of Fah. add 100, multiply the sum by ·00564, and the sixth power of the product equal the force in inches of mercury; which, being multiplied by ·491, equal pounds per square inch elastic force.

Suppose the temperature of steam 262° Fah. $262° + 100 \times \cdot00564 = 2\cdot041686^6 = 74$ inches of mercury; and $74 \times \cdot491 = 36\cdot3$ lbs. elastic force.

12. *What is expansibility?*

Expansibility is the amount of force that steam is capable of exerting, by the recession of its

particles from one another, so that it occupies a greater space, while its weight remains the same: commonly termed expansive force.

13. *How are the properties of steam by expansion estimated?*

Steam of any given density expanded to double its volume exerts then half its original force; if expanded to three volumes, it will then exert one-third its original force; if expanded to four volumes, is then capable of exerting one-fourth its original force, &c., in an inverse ratio with expansion; hence the following rule relative to the steam-engine:—As the whole distance passed through by the piston, both before and after expansion, is to that portion passed through previous to the steam being cut off, so is the pressure of the dense steam to the pressure after expansion.

Suppose steam at 20 pounds, or 5 pounds above the atmospheric pressure, and cut off at 15 inches of the stroke, what force will the steam exert when expanded to 60 inches?

$$60 : 15 :: 20 : 5 \text{ lbs.}; \text{ or } \frac{15 \times 20}{60} = 5 \text{ lbs.}$$

14. *What is latent heat?*

Latent or concealed heat, occasionally designated "heat of fluidity," is an excess of caloric or heat in steam, that is not discoverable otherwise than by a measurable amount of practical effect; and by such means it has been satisfactorily proved that the total amount of latent and indicated caloric in steam of water at all temperatures is a constant sum, viz. 1212° Fah., the latent heat at 212°, or boiling point, being 1000°, or very nearly so. Water at the boiling point, or 212° Fah., requires about 5½ times the quantity of heat to convert it to a state of steam as it did to raise it from 32° to the boiling point; and then the temperature, as indicated by a thermometer, is not elevated by the excess of caloric, but remains an equal quantity, viz. 212°.

15. *Are all waters equally efficacious to the production of steam?*

No; from sea-water; or other waters holding salts similarly in solution, by which the gravity is increased, steam is not produced of an equal elasticity at an equal degree of temperature, because fresh water boils at 212° Fah., whereas

sea-water, equally circumstanced, does not boil until raised to a temperature of 213·2°. From a saturated solution of sea-water at a temperature of 212° Fah., the force of vapour produced is only about 11·37 pounds per square inch elastic force; whereas the vapour from fresh water at an equal temperature is 14·7 pounds; and, under similar circumstances, sea-water at 220°, the force of vapour equal 13·25 pounds; whereas from fresh water at 220°, the force of vapour equal about 17·5 pounds per square inch.

16. *How is the increased gravity or saltness of the water to be ascertained?*

It may be ascertained by means of an hydrometer properly graduated into twelve divisions or degrees, the point of least buoyancy or greatest immersion being in that of fresh water, and the other point, or greatest buoyancy and least immersion, in that of water containing $\frac{1}{8}\frac{2}{3}$ds its weight of salt, the water then being in a state of saturated solution. All sea-waters do not hold in solution equal degrees of saline matter, the water as tested in one locality being in excess to that

of another, as the following—that of the British Channel being 1:—

The Baltic Sea equal . .	0·19
The Black Sea . . .	0·61
The Irish Channel . .	0·96
The Mediterranean Sea .	1·11
At the Equator . . .	1·12
North Atlantic . . .	1·16
Sea of Marmora . . .	1·18
South Atlantic . . .	1·20
Dead Sea	10·86

17. *What is the difference of the temperatures relative to the production of steam at equal densities, from those of fresh and sea-waters individually?*

Sea-water naturally holds in solution $\frac{1}{33}$d its weight of salt, which becomes gradually augmented by evaporation; each grade as approaching to saturation requiring a higher degree of temperature in attaining the boiling point;—thus, at $\frac{2}{33}$ds of saturation, the boiling point is 214·4° Fah.; at $\frac{3}{33}$ds it is 215·5°; and at $\frac{4}{33}$ds, beyond which grade of saturation the water in a steam or marine boiler ought never be allowed to exceed, the

boiling point is elevated to 216·7°; hence, to find the degree of temperature at which steam of a given density would be obtained from salt water equal to that from fresh water, the excess of temperature due to the saltness of the water must be added; thus—

Suppose the temperature to produce steam at 12 pounds per square inch from fresh water be 245·1° Fah., the temperature to produce the same from water holding $\frac{4}{33}$ds its weight of salt, will be

$$245{\cdot}1 + 4{\cdot}7 = 249{\cdot}8° \text{ Fah.},$$

4·7 being the difference between 212° and 216·7.

18. *How is approximated saturation of the water in the boiler, to an injurious extent, prevented?*

By constant extraction of a portion of the water by means of brine pumps, or by brine cocks, from or near the bottom of the boiler; also by frequently blowing out an indicated accumulation of the feed water which has been intentionally forced into the boiler during a given period of time, say, at the greatest extent, the end of every two hours.

19. *Observing, relative to the steam-engine at*

sea, the high degree of temperature necessary for the production of steam from sea-water, and also the loss of heat that must be occasioned by the frequent changing of the water in the boiler, through which to prevent saturation,—is no advantage attempted whereby to effect a saving of fuel, and compensate in some measure for the extra quantity of heat required?

Yes, by means of a refrigerator, that is, a vessel of any convenient form containing a number of tubes, into which vessel, and surrounding the tubes, the saturated water or brine from the boiler is conducted in its course outward. And through the interior of the tubes the water to the boiler is compelled to pass by the action of the feed pumps; hence, by such means, a portion of the heat from the brine is abstracted by the feed water previous to its entering the boiler, thus effecting a saving in proportion to the quantity of heat it may by such means imbibe.

20. *By such application, how is the theoretical amount of advantage estimated?*

Rule:—From 1212° subtract the heat of the brine after leaving the refrigerator; multiply the

remainder by the grade of saturation, and from the temperature of the water in the boiler subtract also the heat of the brine after leaving the refrigerator; add together the product and the remainder obtained by each process: then, as the sum of the two is to the remainder, so is the quantity of fuel required in a given time to the quantity saved, in equal terms of unity.

21. *Suppose, in a marine boiler, the water be maintained at three times the saltness of sea-water, and at a temperature of* 244° *in the boiler, the water from the refrigerator at* 100°, *and the consumption of coals per day, without the refrigerator, thirty-six tons,—what, with the refrigerator, might be the anticipated amount of saving during the same period of time?*

$$\left.\begin{array}{l} 3 \times (1212° - 100°) = 3336° \\ \text{and} \quad 244 \ -100 \ = \ 144 \end{array}\right\} + = 3480$$

Then, as 3480 : 144 : : 36 : 1·49 tons of fuel saved.

22. *In regard to boilers for the generation of steam, what are the best proportions of capacity, heating surface, and extent of furnace, so as to*

supply efficiently with steam any dimension of steam-engine given?

When practicability will admit, the capacity for water and steam ought not to be less than twenty-five cubic feet, extent of heating surface not less than nine square feet, and one square foot of furnace bars to each nominal horse-power.

23. *What is meant by the term nominal horse-power of an engine?*

By nominal horse-power is to be understood that of an engine having a cylinder of a given diameter and a given length of stroke, with a constant, uniform, effective pressure of seven pounds per square inch on the piston.

The rule for estimation being as follows:—Multiply the square of the cylinder's diameter in inches by the cube root of the stroke in feet, and by ·0213; the product is the nominal horse-power. Suppose a cylinder of 30 inches diameter with a stroke of six feet.

$30^2 = 900$ and $\sqrt[3]{6} = 1{\cdot}817$, hence $900 \times 1{\cdot}817 \times {\cdot}0213 = 34{\cdot}8$ horse-power.

24. *What is the expected evaporation of water,*

or volume of steam generated by a boiler of the preceding proportions to each horse-power?

About thirty-three cubic feet of steam generated per minute, or one cubic foot of water evaporated per hour by fuel of an average quality, or one pound of coal to about 8·5 pounds of water evaporated.

25. *How is the pressure or elastic force of steam determined relative to the steam-engine practically?*

By means of the safety-valve, that is, properly, a circular disk covering a circular opening in the top or upper part of the boiler, and either loaded directly or indirectly by the action of a lever and weight, or spring balance, to any degree of pressure required.

26. *What is meant by the action of the lever?*

The action of the lever is the accumulated effect of its weight upon the valve, more than would be effected by actual gravity. Thus, if the distance between the fulcrum and the valve be equal to half the lever's length, the same being of parallel dimensions, the action upon the valve equals the weight of the lever; but in proportion as the dis-

tance between the fulcrum and the valve is lessened, so is the action or tendency of the lever to press down the valve increased.

27. *When the required pressure upon the safety-valve is given, also the diameter of the valve, by what mode of calculation is the required amount of weight upon the valve or lever determined?*

Square the diameter of the valve, that is, multiply the diameter by the diameter, which product being multiplied by the decimal number ·7854, expresses the area of the valve in equal terms of unity; and if the weight be to act directly upon the valve, multiply the area by the pressure required; the product is the weight required, plus the weight of the valve: but if the pressure is to be effected through the intervention of a lever, then the weight required on the lever is less, equal to the number of times the distance between the fulcrum and the weight exceeds the distance between the fulcrum and the valve.

28. *What is meant by the expression—"area" of the valve?*

The area is the amount of surface exposed to the action of the steam whereby to effect a raising

of the valve from its seating, and expressed in terms as the measurement of its diameter; for instance, if the diameter be inches, the area will be square inches; and so of any other measure in which the diameter is taken.

29. *Why square the diameter of the valve and multiply by* ·7854, *to find the area?*

Because the area of a circle whose diameter is unity or 1, is to the area of a square whose side is unity, as ·7854 to 1. If the pressure of steam on a square inch be multiplied by ·7854, the product is the pressure on a circular inch, in equal terms of unity

30. *If the pressure of steam be expressed by the circular inch in place of square inch, how is the amount of pressure on the square inch to be ascertained?*

Divide the pressure on a circular inch by ·7854; the quotient is the pressure on that of a square inch, in equal terms of unity; or, because 1·2733 is the reciprocal of ·7854, multiply the pressure by that number, and an equal purpose will be effected.

31. *If a square inch be made the unit of area, whereby to determine the amount of pressure on a safety-valve, and a pound the unit of weight, how many pounds must there be attached, directly, on a valve* $7\frac{1}{4}$ *inches diameter, to effect a pressure of eight pounds per square inch.*

$7{\cdot}25^2 \times {\cdot}7854 = 41{\cdot}282$ inches, the area of the valve, and $41{\cdot}282 \times 8 = 330{\cdot}256$ pounds, including the weight of the valve.

32. *If, to effect the above purpose of pressure, a lever of* 45 *inches in length were applied, the distance between the fulcrum and the valve being six inches; what weight must be laid on the end of the lever, or what would be the indicated pressure by a spring balance?*

$$\frac{45}{6} = 7{\cdot}5 \text{ and } \frac{330{\cdot}256}{7{\cdot}5} = 44{\cdot}034 \text{ lbs.}$$

Or,

$$\frac{330{\cdot}256 \times 6}{45} = 44{\cdot}034 \text{ lbs., as before; but in}$$

neither case is the action of the lever taken into account, and which ought to be deducted, as well as the weight of the valve.

33. *Suppose a given diameter of valve is required to be replaced by two or more, and of diameters equal or unequal to each other, but in total amount of area equal to the first; by what mode of calculation is this to be effected?*

All circles are in relation to each other as the squares of their diameters; hence, if the given diameter be squared and divided into the various required proportions, the square roots of the quotients give the various diameters required.

Thus, suppose it were required to form two safety-valves, whose united areas equal one of six inches in diameter, but, of the two, the area of the one to be twice that of the other: $6^2 = 36$; but the one is to be twice that of the other; hence it must be divided into three parts; $36 : 3 = 12$, and $12 \times 2 = 24$: consequently the one must contain 12, and the other 24 inches; then $\surd 12 = 3{\cdot}464$, and $\surd 24 = 4{\cdot}899$ inches diameter.

34. *Is there no other method adopted whereby to test the steam's elastic force in a boiler, than by means of a safety-valve?*

Yes, by an inverted syphon containing mercury sufficient to overcome the pressure of the steam;

2·04 inches in height of the column being a counterpoise to a pressure of one pound; but as the syphon consists of two columns, a rise of about one inch, indicated by the mercury in the column open to the atmosphere, shows an increase of pressure equal to one pound per square inch in the boiler.

35. *Is the indicated pressure of steam by a safety-valve, or otherwise, the total amount of effective force whereby to produce motion in a steam-engine?*

In those on the non-condensing principle it is; but in a condensing engine, if a perfect vacuum is obtained, fifteen pounds per square inch must be added; this, however, being unattainable in practice, through imperfect condensation, the proper amount to be added is fifteen pounds per square inch, minus the resisting vapour in the cylinder, as indicated by a barometer attached.

36. *What is a barometer?*

An instrument for measuring the density of vapour remaining in the condenser of a steam-engine; it consists generally of a glass tube upward of thirty inches in length, placed vertically,

with its bottom end sufficiently immersed in a cup of mercury, the top end communicating with the condenser by means of an iron pipe. When the engine is at work, the perfection of vacuum is indicated with the rise of mercury in the tube, by the atmospheric pressure on the surface of the mercury in the cup; thirty inches in height indicating a perfect vacuum, but more than twenty-eight inches is seldom in practice attained.

37. *What is meant by a vacuum?*

By vacuum is meant a void or empty space; hence, in a condensing engine with a perfect vacuum, steam at fifteen pounds per square inch is of equal effect to that of steam at thirty pounds per square inch in one of the non-condensing principle.

38. *What is meant by condensation?*

Condensation of steam is the causing of a closer approach of its particles through the abstraction of heat. The steam being admitted into a close vessel called a "condenser," by means of a communication with the cylinder or otherwise, its superior degree of density expels through a valve

the atmospheric air which was therein retained; a jet of cold water is then opened to rush in and mix with the steam, by which its aeriform properties are destroyed, and a vacuum of more or less perfection obtained.

39. *Is there any proportionate quantity of water required for the condensation of steam at a given temperature?*

Yes; the proportionate quantity is as estimated by the following rule:—From 1212°, or commonly reckoned amount of the latent and sensible, or indicated temperature of steam, subtract the temperature of the condensed water, divide the remainder by the temperature of the condensed water minus the temperature of the condensing water, and the quotient is the number of times that the quantity for condensation must exceed that from which the steam is formed.

40. *What will be the relative quantities of water between that of formation and condensation of steam, the temperature of the steam being* 222·6° *Fah., or three pounds above the pressure of the atmosphere, the temperature of the condensing*

water being at 52°, *and the required temperature of the water after condensation to be* 100°?

$\frac{1212° - 100°}{100° - 52°} = 23{\cdot}17$ times the quantity of water for condensation to that from which the steam is formed; and as per table of the volume of steam generated under different pressures—one cubic foot of steam generated at a temperature of 222·6° Fah., requires in formation 1·226 cubic inches of water; hence $23{\cdot}17 \times 1{\cdot}226 = 28{\cdot}4$ cubic inches of water at 52° that will be required to condense one cubic foot of steam of the given temperature to water at 100°.

41. *If steam of high density be employed in a steam-engine, is effective condensation rendered more difficult of being obtained?*

No; because, when steam of high density is employed, only a small portion of the steam is allowed to enter the cylinder, the movement of the piston being continued by expansive force; hence, the power of the engine is augmented, and the steam advantageously lessened in density by expansion, or increased bulk.

42. *What is the difference, when applied to the steam-engine, between the terms* duty *and* power?

Duty implies a certain amount of work done by a certain amount of fuel without reference to time; but the power is the number of times 33,000 pounds the engine is capable of raising one foot high per minute.

43. *What is the amount of advantage in working a steam-engine expansively?*

The advantage of working steam expansively is the economizing of fuel, the amount of advantage being as the quantity of steam saved, minus the diminution of mechanical energy by expansion.

44. *How is the amount of mechanical effect of the steam to be ascertained?*

Divide the length of the piston's stroke by the distance into the cylinder the dense steam has been admitted previous to its being cut off, and the hyperbolic logarithm of the quotient is the increased efficacy due to expansion, when the force of the dense steam is 1.

Thus, suppose the stroke of an engine equal

4½ feet, the dense steam being admitted through 1½ feet: 4·5 ÷ 1·5 = 3, the hyperbolic logarithm of which is 1·0986, or efficiency due to expansion, and 1·0986 + 1 = 2·0986, the ratio of elastic force.

Again, suppose the pressure of the dense steam equal 27 pounds per square inch: 4·5 ÷ 1·5 = 3, and 27 ÷ 3 = 9, logarithm of 3 + 1 = 2·0986 × 9 = 18·887 pounds per square inch, ratio of elastic force, and 18·887 × 4·5 = 84·99 units of mechanical effect produced throughout the length of the stroke.

45. *How is the steam's elastic force ascertained at any portion of the stroke after expansion?*

Multiply the force of the dense steam in pounds per square inch, by the numerator of the fraction expressing that portion of the stroke passed through when the steam is cut off; divide the product by the numerator of the fraction expressing the whole amount of stroke passed through by the piston where the estimated force of the steam is required after expansion, and the quotient is the force per square inch in equal terms of unity.

Let steam be admitted at 25 pounds per square inch, and cut off when the piston has performed $\frac{3}{12}$ths of its stroke; to find the amount of elastic force that the steam will exert at $\frac{24}{12}$ths of the stroke:

$$\frac{25 \times 3}{24} = 3{\cdot}125 \text{ lbs. per square inch.}$$

Or, if steam at 25 pounds per square inch be cut off at half the stroke; to find the amount of elastic force exerted at three-fourths:

$$\frac{25 \times {\cdot}5}{{\cdot}75} = 16{\cdot}66 \text{ lbs. per square inch.}$$

46. *Suppose steam at a given density is to be cut off at a certain point, so as to maintain a required degree of elastic force at the termination of the stroke, how is that point to be determined?*

Multiply the required elastic force of the steam in pounds per square inch, at the termination of the stroke, by the length of the stroke in inches, and divide the product by the given force of the dense steam in pounds; the quotient is the distance from the commencement of the stroke at which the steam must be cut off.

Thus, suppose steam at 20 pounds per square

inch, length of stroke 24 inches, and, at the termination of the stroke, the steam to have an elastic force of 7 pounds per square inch:

$\frac{7 \times 24}{20} = 8{\cdot}4$ inches from the commencement of the stroke.

Again, suppose the above application to be in that of a condensing-engine; it might be required to determine how far below the line of atmospheric pressure the steam pressure would indicate, the dense steam being at 20 pounds per square inch, or 5 pounds above the pressure of the atmosphere.

$\frac{20 \times 8{\cdot}4}{24} = 7$ and $15 - 7 = 8$ lbs. below the pressure of the atmosphere.

47. *By what means is the steam cut off, whereby to effect any required amount of expansion in the cylinder of a steam-engine?*

By the lap on the steam-slide or slide-valve, the steam may be cut off at half, and by an expansion-valve, at any point of the stroke required.

48. *What is meant by lap on the steam-slide or slide-valve?*

By the lap of the slide-valve is meant a certain additional breadth of its face on the steam-side, more than sufficient to cover the aperture in the cylinder when the valve is at half-stroke.

49. *When the point of stroke is given at which the steam is required to be cut off by the slide-valve, how is the necessary additional extent of valve-face to be ascertained?*

Divide by the length of the piston's stroke in inches the distance the piston has to travel when the steam is cut off; multiply the square root of the quotient by half the travel of the valve, also in inches, and from the product subtract half the valve's lead; the remainder is the lap or cover required.

Thus, suppose an engine with a stroke of 36 inches, the steam being required to be cut off when the piston has passed through 23·4 inches, the travel of the valve being 5 inches, and the lead one-fourth of an inch.

$36 - 23{\cdot}4 = 12{\cdot}6$ inches the piston has to travel.

$\sqrt{\frac{12{\cdot}6}{36}} = {\cdot}5916 \times 2{\cdot}5$, or half the travel of the valve $= 1{\cdot}479 - {\cdot}125$ or half the lead $= 1{\cdot}354$ inches, the lap or cover required.

50. *Suppose the lap, lead, travel of the valve, and stroke of the piston to be given, and also the required point at which the steam is to be cut off; how then?*

Reverse the former rule; thus, to the lap of the valve on the steam side in inches, add half the lead, divide the sum by half the travel of the valve, multiply the square of the quotient by the piston's stroke in inches, and the length of the stroke minus the last product equal the distance the piston will have travelled when the steam is cut off.

Suppose, as before, that the lap of the valve equal 1·354 inches, half the lead ·125 inches, and stroke of piston 36 inches:

$\frac{1{\cdot}354 + {\cdot}125}{2{\cdot}5} = 1{\cdot}479^2 \times 36 = 12{\cdot}6$ and $36 - 12{\cdot}6 = 23{\cdot}4$ inches the piston will have travelled when the steam is cut off.

51. *What is meant by the lead of the valve?*

The lead is what the steam aperture is open, for admission of the steam when the piston is at the top or bottom of the cylinder, and about to commence the returning stroke.

52. *What is the travel of the valve?*

The travel of the valve is an amount of movement caused by the eccentric through the intervention of levers or otherwise; and in total extent equal the width of the two steam openings, plus the lap of the valve over each opening. But in direct-action engines, standing vertically, the lead is necessarily greatest for the up stroke, in order to counteract, in some measure, accelerated motion, which the weight of the piston, in falling, tends to obtain.

53. *And what is an eccentric?*

An eccentric is a circular pulley whose centre of revolution is more or less distant from its centre of formation; and by means of a surrounding hoop, in which it revolves, an alternate reciprocating movement is obtained to the valve through

uniform circular motion of the crank-shaft. The degree of eccentricity or extent of throw given by an eccentric is equal to twice the distance between its centres of formation and revolution, and when practicability will admit, equal to the travel of the valve.

54. *When the throw of eccentric and travel of valve are unequal, so as to cause a weigh-shaft and intervention of levers, how are the various lengths of levers obtained?*

For eccentric lever, multiply the throw of eccentric by length of valve lever, and divide by travel of valve.

For valve lever, multiply the travel of valve by eccentric lever, and divide by throw of eccentric. Thus, suppose the throw of an eccentric equal 4 inches, travel of valve 8 inches, lever on weight-shaft, to which valve-spindle is attached, twelve inches.

$4 \times 12 \div 8 = 6$ inches, length of lever for eccentric rod.

Or $8 \times 6 \div 4 = 12$ inches, length of lever for valve-spindle.

55. *If any doubt exist relative to an eccentric rod being of an improper length, when in its working situation on the engine, how is its accuracy or inaccuracy to be tested?*

Place and secure the valve at half-stroke by means of the packing or otherwise, bring the eccentric round upon the shaft to either extremity of throw, mark upon the rod the centre or diameter of the stud in the weigh-shaft lever, turn the eccentric round to the other extremity, and mark the stud upon the rod there also. If the receptacle in the rod for the stud be immediately equidistant, the rod is of a proper length; but if not, the rod must be lengthened or shortened equal to half the deviation observed.

56. *It is essentially necessary, no doubt, that the various rods in a steam-engine, by which to communicate motion from one point to another, be in length to the greatest degree of exactitude; how are the dimensions of length for the principal rods thus to be determined?*

The proper length for the connecting-rod of a beam-engine, is the perpendicular distance be-

tween the centre of the beam and centre of fly-wheel shaft.

The proper length for the side-rods of a lever-engine, is the perpendicular distance between the centre of lever and centre of piston cross-head at half-stroke.

The proper length for connecting-rods of direct-action engines, is the distance between the centre of crank-axle and centre of piston cross-head at half-stroke.

The proper length for an eccentric-rod, is the distance between the centre of fly-wheel shaft, or centre of revolution, and centre of stud in traverse shaft, when the valve is at half-stroke.

57. *In speaking of an engine where the motion of the piston is communicated by means of a beam vibrating upon an axis, or by side-levers similarly actuated, what is to be understood when stated that the centre of the cylinder must be set half the versed sine in toward the centre of the beam?*

By versed sine is meant the difference between a straight line and that of a curved line, described by the centre of the stud in the end of the beam when moved through the whole stroke; hence the

centre of the cylinder must coincide with half the distance between the chord and its arc as described by the beam.

58. *Knowing the radius of the beam and the length of stroke, how is the versed sine to be ascertained?*

The versed sine is the difference between the base and hypotenuse of a triangle, the hypotenuse being the radius of the beam, and the perpendicular of the triangle half the length of stroke; hence the rule:—

To the radius of the beam add half the length of stroke, multiply the sum by their difference, and the square root of the product subtracted from the radius of the beam, equal the versed sine.

Thus, suppose an engine with an equal-ended beam 14 feet in length, and the stroke of the piston five feet, what is the versed sine?

$7+2{\cdot}5=9{\cdot}5$ and $7-2{\cdot}5=4{\cdot}5$: then $\sqrt{9{\cdot}5\times4{\cdot}5}$ $=6{\cdot}53$ and $7-6{\cdot}53={\cdot}5$ of a foot, the versed sine.

59. *But how is it to be ascertained what portion of a foot the above remainder is, in our common*

mode of measurement by inches, or twelfths of a foot?

Multiply the decimal by 12, and the whole number, if any, is inches; and again multiply the remaining decimals by 8, the whole number, if any, is eighths, &c.

60. *How is the parallel motion in an engine, with regard to accuracy or inaccuracy, to be tested and adjusted?*

At half-stroke, if the piston-rod remain freely by the motion's guidance in the centre of the cylinder, and at the same time the parallel and radius bars parallel with the centre of the beam or side-levers, then may be concluded that they are each of a proper length, and that the radius-shaft or studs, as may be, are in their proper situations;—raise and lower the piston to the full extent of the stroke; and if, at both top and bottom, the cross-head is thrown outward from the centre of the cylinder, the stud in the beam or lever, which gives proper movement to the radius-bars, is too far out from the centre of the beam; but if, on the contrary, the cross-head be inclined toward the centre of the engine, then the stud is

not of sufficient distance from the centre of the beam, and must be set out accordingly.

61. *How is the proper amount of velocity determined for the piston of a steam-engine?*

There are various rules used by which to obtain the most beneficial velocity to produce a maximum of useful effect; but 128 times the cube root of the length of stroke, as the velocity in feet per minute, is perhaps a rule equally simple and efficient to that of any other; thus, suppose an engine with a stroke of 5 feet:

$\sqrt[3]{5} \times 128 = 218{\cdot}86$ feet velocity per minute.

62. *How is the effective power of an engine properly estimated?*

The power of an engine may be readily computed by the following rule:—Multiply the area of the piston in square inches, by the uniform force of the steam in pounds per square inch throughout the whole stroke, and by the velocity of the piston in feet per minute; deduct from the product $2\frac{1}{2}$ pounds per square inch for friction, &c., divide the remainder by 33,000, and the quotient is the actual effect of the engine expressed in terms of horse-power.

Suppose an engine with a cylinder of 40 inches diameter, the piston's velocity 240 feet per minute, and steam at 12 pounds per square inch of uniform elastic force:

$40^2 \times .7854 = 1256.64$ inches area, and 12 lbs. $- 2.5 = 9.5$: then $\frac{1256.64 \times 9.5 \times 240}{33{,}000} = 86.52$ horse-power.

63. *How is the degree of uniform elastic force of the steam in the cylinder most readily obtained?*

The most efficacious and also the most simple mode is through the application of an indicator, now an instrument so well known that comment upon its construction is unnecessary; its properties are those of describing by a pencil upon paper, a figure or diagram approximating in form that of a rectangle, subject to deviation of form with the merits or demerits of the engine's productive effect. The mean breadth or height of the figure is the elastic force of the steam in terms as the scale of the indicator, the length is the amount of revolution given to the paper on which the diagram is described during the piston's performance of its stroke.

64. *How is an application of the indicator effected?*

The usual mode of application is by screwing the indicator into the cylinder cover, and obtaining the required movement to the paper by means of a small line attached to one of the radius-rods; but such application cannot always be effected, particularly in marine-engines; hence, other parts of the engine having a relative movement to that of the piston must of necessity be resorted to; and, if required, because of the motions of the parts of the engine selected and that of the indicator being unequal, a pulley and axle may be introduced, so as to qualify the various movements and render them suitable to each other as compulsion may demand.

65. *By what means is the diagram obtained?*

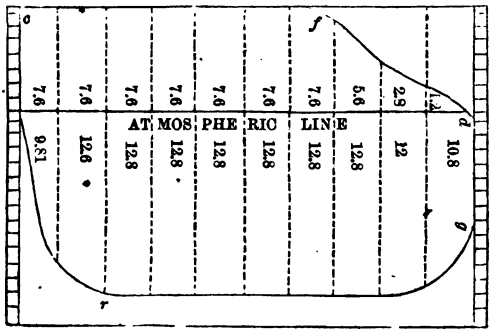
The indicator being fixed and the movement of the paper properly adjusted, the pencil at the same time having its point pressed upon the paper by the spring, allow the engine to make a few revolutions previous to opening the cock, by which means a horizontal line is traced upon the paper, and distinguished as the atmospheric line, because

it is a line of distinction between the force of the steam above that of atmospheric pressure, and the force of the steam rendered available by the extent or quality of the vacuum obtained by means of the condenser. Open the cock, and if the engine be upon the descending stroke, the steam in the cylinder will instantly raise the piston of the indicator, and by the motion of the paper, the pencil still pressing thereon, the top side of the diagram will be described. In the ascending stroke, and during the time that the bottom side of the diagram is being traced, the piston of the indicator, by the surrounding atmosphere, is pressed down below the atmospheric line to some point on the scale or index, approaching the indication of a pure vacuum in proportion to the density of the resisting vacuum in the cylinder, and the degree of rarefaction of the air in the engine-room, which ought to be carefully notified. The up-stroke having terminated, the diagram is completed; hence is delineated the mean elastic action of the steam above the atmospheric line, and also the mean extent of the vacuum underneath it; or perhaps, more properly, the amount of available effect of the steam obtained through the removal

of atmospheric pressure by means of the condenser.

66. *In the following diagram, how are the various deviations from that of a rectangle to be explained or accounted for?*

From *c* to *f*, steam of equal density is continued. At *f* the steam is cut off, and from *f* to *d* the piston is impelled by the steam's expansive force. At *d* the upper eduction-valve opens. At *g* the downward stroke is completed, and at *r* the valve begins to open. Any rounding of the diagram at *c*, or starting corner, shows a defect from want of sufficient lead being given to the valve; and rounding at *g* shows a defect, by the eduction passages being too small.



The line under the diagram and parallel to the atmospheric line is $\frac{1}{10}$ths distant, and represents the perfect vacuum-line, the space between showing the amount of force with which the uncondensed steam or vapour opposes the ascent or descent of the piston at every part of the stroke.

67. *How is the uniform force of the steam estimated from the diagram taken?*

Divide the diagram in the direction of its length into any convenient number of equal parts, through which draw lines at right angles with the atmospheric line, add together the lengths of all the spaces taken in measurements corresponding with the scale on the indicator, divide the sum by the number of spaces, and the quotient is the mean effective pressure on the piston in pounds per square inch.

Thus, the diagram taken shows an effective pressure of steam above the atmospheric line, of 6·28 pounds per square inch, and an effective pressure of 12·2 pounds underneath, or a uniform effective force of 18·48 pounds per square inch on the piston; hence, suppose the engine to have a cylinder of 70 inches in diameter, and the piston

moving at a velocity of 231 feet per minute, the effective power of the engine may be estimated as follows:—

18·48 — 2·5 = 15·98 pounds per square inch, after deducting 2·5 pounds for friction, &c., then $\frac{70^2 \times \cdot 7854 \times 231 \times 15 \cdot 98}{33{,}000} = \frac{14204929 \cdot 914}{33{,}000} =$ 400·146 horse power.

68. *The relative volumes of steam and water being known, also a given quantity or volume of steam expended in a given time, what will be the amount of water evaporated for the volume of steam expended?*

RULE.—To the temperature of the steam in degrees of Fah., add 459, multiply the sum by 76, divide the product by the elastic force in inches of mercury, and the quotient is the volume of steam compared with the volume of water.

EX.—Suppose 500 cubic feet of steam at a temperature of 240·7° be required for an engine per minute, the quantity of water in theoretical estimation necessary for the production of that amount of evaporation is 240·7° = 51 inches of mercury elastic force.

$\frac{240{\cdot}7 + 459 \times 76}{51} = \frac{53177}{51} = 1042{\cdot}7$ volume of steam to one of water.

And at the common atmospheric pressure one cubic inch of water produces about one cubic foot of steam, and at all pressures bears a relative proportion; hence it follows that $\frac{1728 \times 500}{1042{\cdot}7} = \frac{864000}{1042{\cdot}7} - 828{\cdot}6$ cubic inches of water required.

Or, from the table of steam generated under different pressures, steam at a temperature of 240·7°, the cubic inches of water in a cubic foot of steam equal 1·658; hence $1{\cdot}658 \times 500 = 829$ cubic inches of water.

69. *For a steam-engine, is the preceding rule applicable by which to determine the capacity of feed-pump for a boiler?*

No; it is merely the quantity of water evaporated in theory; practice shows leakage, priming, and other contingencies to provide against; hence the feed-pump ought not to be less than three and a half times the estimated capacity for theoretical evaporation. The capacity for a feed-pump is obtained by the following rule:—

Multiply the capacity of the cylinder in cubic inches by the total pressure of the steam in pounds per square inch, divide the product by 4800, the quotient equal the capacity of pump in cubic inches.

Ex.—Suppose a condensing engine with a cylinder 33 inches diameter, and a stroke of five feet, or 60 inches, the total pressure of steam 21 pounds, or six pounds above the atmospheric pressure, what must be the pump's capacity?

$$\frac{33^2 \times \cdot 7854 \times 60 \times 21}{4800} = \frac{1077678}{4800} = 224 \cdot 5$$

cubic inches.

70. *That being the proper capacity, how are the dimensions of pump tested or determined?*

If the length of the stroke is given, divide the capacity by the stroke in inches, and the square root of the quotient multiplied by 1·12837 equal the diameter in inches.

Ex.—Suppose the capacity of a pump to be 224·5 cubic inches, and an unchangeable length of stroke of 11 inches given, to find the necessary diameter.

$$\frac{224 \cdot 5}{11} = \sqrt{20 \cdot 4} \times 1 \cdot 12837 = 5 \cdot 1 \text{ inches nearly.}$$

Or, $5{\cdot}1^2 \times 7854 = 20{\cdot}428$ and $\frac{224{\cdot}5}{20{\cdot}428} = 11$ inches length of stroke.

71. *At what temperature ought the condenser to be kept, or otherwise, at what temperature ought the condensed water to be delivered into the hot well of a condensing engine, that the engine may produce a maximum of effect by condensation?*

At 100°, when the water for injection is not less than 50°. But if a reduction of temperature can be obtained by the use of colder water, then a better effect will be produced when the condensed water is delivered at about 80°. For a land condensing engine, the capacity of the cold water pump commonly is one forty-eighth the capacity of the cylinder.

But suppose the temperature of the injection or condensing water to be 32° and 80° respectively, the relative proportions of each for condensation to maintain the condenser at 100° will be, $100° - 80° = 20$, and $100° - 32° = 68$; consequently the available temperatures of the waters to condensation = 20° and 68°, or the quantities for injections are as 20 to 68, and in like proportion at any other given temperature.

72. *When the injection orifice in a steam-vessel becomes by any means choked up, the usual mode adopted for clearing is that of blowing through by the force of the steam; how is the necessary force of the steam to be ascertained?*

A column of water whose base equal one square inch and height one lineal foot is ·434 pounds, hence multiply ·434 by the depth in feet from the surface of the water to the centre of the pipe, and the product equal the pressure of steam in pounds that will equipoise that column; but an overwhelming force of two or three pounds must be applied by which to remove the obstruction.

73. *Suppose a steam-vessel to be propelled through the water at a certain rate of speed by a known amount of power; how is the proportionate increase or decrease of speed ascertained by any other amount of power given?*

The power required to propel a vessel through the water is as the cube of the velocity; hence, if 300 horses' power propel a vessel at a velocity of $9\frac{1}{2}$ knots per hour, the velocity by 450 horses' power will be

$$\sqrt[3]{\frac{9{\cdot}5^3 \times 450}{300}} = \sqrt[3]{\frac{385818}{300}} = 10{\cdot}87 \text{ knots per hour.}$$

74. *Is the increase or decrease of fuel with a difference of the vessel's speed as the cube of the velocity also?*

No; steam-vessels, to be propelled at an increased velocity through the water, require an augmentation of fuel equal to the square of the increased speed, multiplied by the distance steamed, or to be steamed over; hence, suppose 80 tons of coal be a sufficient quantity for a voyage of 1000 miles, at a speed of eight knots per hour, the quantity requisite to complete a distance of 1500 miles at a speed of ten knots per hour, will be—

$8^2 : 10^2 :: 80 : 125$, and $1000 : 125 :: 1500 : 187{\cdot}5$ tons.

Again: Suppose 400 tons of coal be a sufficient quantity for generating steam at a rate of ten knots per hour, at what rate per hour must the vessel steam, so that 300 tons will complete the voyage?

$400 : 10^2 :: 300 : 75$, and $\sqrt{75} = 8{\cdot}66$ knots per hour.

75. *The distance run or passed over by vessels at sea is commonly computed in knots or nautical*

miles of 2028 *yards, English, the statute mile being* 1760; 9·84 *knots are nearly equal to* 11·34 *statute miles. Hence, if a vessel be going at a rate of* 8½ *knots per hour, how many English or statute miles is that corresponding to?*

9·84 : 11·34 : : 8·5 : 9·79 miles, or 1·1522 × 8·5 = 9·79 as before.

But the knot sometimes causes confused estimation of a vessel's speed or distance run, because of its length being made to depend upon the length of a measured degree on the earth's surface, which varies in different latitudes, as under:

The length of a degree as measured at

Peru . . .	0° equator	= 68·732	English statute miles; hence the knot	= 2016·17	yards.
United States	30° 12′ 0″	= 68·896		= 2020·95	"
Rome . .	42° 59′ 0″	= 68·998		= 2023·94	"
France . .	44° 50′ 0″	= 69·054		= 2025·58	"
England .	51° 29′ 44″	= 69·146		= 2028·28	"
Sweden . .	66° 20′ 10″	= 69·292		= 2032·56	"

76. *Relative to a screw for the propelling purpose of a steam-vessel, how is the pitch ascertained from the dimensions that are left accessible after a considerable portion of the helix being cut away?*

From the square of either blade's extremity

subtract the square of either's height, and the square root of the remainder is to the height as the circumference of the screw is to the pitch or lineal distance passed through by one revolution, providing there was no slip.

Suppose the section of a screw as follows:— Breadth at extremity of either blade $4\frac{1}{2}$ feet; height, or twist of each, $1\frac{3}{4}$ feet; and diameter 13 feet:

$\sqrt{4{\cdot}5^2 - 1{\cdot}75^2} = 4{\cdot}13$, and $13 \times 3{\cdot}1416 = 4084$; hence $3{\cdot}13 : 1{\cdot}75 :: 40{\cdot}84 : 17{\cdot}3$ feet, pitch of the screw.

77. *The revolutions and pitch of a screw being known, and also the speed of the vessel, how is the amount of slip ascertained?*

If the speed of the vessel is observed in knots or nautical miles per hour, multiply the pitch of the screw in feet by the number of its revolutions per minute; subtract from the product 101·5 times the speed of the vessel in knots per hour, multiply the remainder by ·00985, and the product is the loss by slip per hour in equal terms of unity. The same rule is equally suitable if observed and required in English statute miles, only instead of

101·5 the speed, take 88; and instead of multiplying by ·00985, multiply by ·0114.

Thus, suppose the pitch of a screw propeller equal 13½ feet, the number of revolutions being 70 per minute, and it is found that the vessel's speed is 8 knots an hour, the amount of slip will be the following:—

$13{\cdot}5 \times 70 - 101{\cdot}5 \times 8 = 133 \times {\cdot}00985 = 1{\cdot}29$ knots slip per hour. Again, if the speed be taken in statute miles:—

$13{\cdot}5 \times 70 - 88 \times 8 = 241 \times {\cdot}0114 = 2{\cdot}74$ miles slip per hour.

78. *When any curve or portion of a circle is given, how is the corresponding radius obtained?*

RULE.—Take any length of straight line, or chord in the curve, and to the square of half its length add the square of the height, or versed sine, divide the sum by twice the versed sine, and the quotient is the radius.

EX.—Suppose a portion of a paddle-wheel ring, in which a line may be stretched 5 feet in length, and the height from the line to the ring measuring 2½ inches, what is the radius?

5 feet = 60 inches and $\frac{30^2 + 2{\cdot}5^{20}}{2{\cdot}5 \times 2} = \frac{906{\cdot}25}{5} =$ 181·25 inches, or 15 feet 1¼ inch radius.

79. *Coals in quality vary considerably for the economic production of steam; thus,* 1 *lb. of the best Welsh is capable of evaporating* 9·49*lbs. of water;* 1 *lb. of the best Newcastle,* 9·01 *lbs.; and Derbyshire, only* 6·77 *lbs.: the average capacity in steam-vessels for stowage of fuel, is from* 45 *to* 48 *cubic feet per ton. Now, supposing by measurement there be found remaining in the boxes* 168¾ *tons, and the average consumption* 22½ *cwt. per hour—how many hours' steaming may there be expected from that quantity, at an equal ratio of expenditure? and how many tons of Newcastle coals must be supplied, by which to produce equal amounts of effect?*

$$\frac{168{\cdot}75 \times 20}{22{\cdot}5} = \frac{337{\cdot}5}{22{\cdot}5} = 15 \text{ hours,}$$

and 9·01 : 337·5 : : 9·49 : 177·735 tons.

Scotch and Welsh coals, in a state for fuel, require per ton about 44 cubic feet capacity for

stowage; and Newcastle coal, in a similar state, 46 cubic feet.

80. *What is meant generally by the term combustion?*

Combustion, under ordinary circumstances, means, chemical union of combustible matter with oxygen at a sufficiently elevated temperature for the generation of heat. Ignition, spontaneously or mechanically, is the source through which increased temperature is incited, and oxygen is the matter by which combustion is supported.

Any combustible substance employed commonly for the purpose of creating and maintaining heat, is termed fuel; but coal, of which there are many varieties, is the principal substance as fuel used in this country, the following of which are the mean of compositions per cent. from different localities.

Specific gravity.	Carbon.	Amount per cent. of Hydrog.	Nitrog.	Sulph.	Oxygen.	Ash.
1·279	80·40	5·29	6·04	1·34	7·67	4·05

8 pounds of fresh water, evaporated from

212° Fah. by 1 pound of coal, is the average quantity.

81. *What are the effects of heat upon liquid substances generally?*

1. Liquefaction,—as the conversion of ice to water.

2. Expansion,—as the increased bulk of water from 39° to 212° Fah.

3. Vaporization,—as the change of water to steam by excess of caloric after 212°; or any other boiling-point to which it may be exposed by constrained pressure.

82. *What are the effects of cold upon liquid substances generally?*

1. Liquefaction,—as the condensation of steam through abstraction of heat by cold water.

2. Contraction,—as the reduction of steam as a vapour to water as a liquid.

3. Solidification,—as the change which water undergoes by reduction of temperature—namely, from a liquid to ice in a solid state. But water from a liquid to that of a solid state is an exception to effects produced upon bodies generally;

for at 39° Fah. water is at its greatest degree of density, or 1·00000; whereas, at 32°, or point of freezing, its bulk is increased to 1·00012.

83. *Are vapours, liquids, and solids expanded regularly by regular increments of heat?*

Atmospheric air, gases, and vapours generally, expand regularly with every increase of temperature, or are similarly augmented in elastic force, if enlargement of bulk be prevented. Hence, whatever amount of expansion will arise by an increased temperature of 12°, half as much will arise from an increase of 6°, twice as much from 24°, &c.; but neither liquids nor solids follow this law. Thus, when water is

at 40°	Fah.	its density equals . .	1·00000
86	"	it is expanded to . .	1·00327
126	"	" " . .	1·01152
212	"	" " . .	1·04012

Again, mercury expands from—

32°	to 212°	Fah.	·018099	The original bulk being 1, or unity.
212	" 392	"	·018184	
392	" 572	"	·018870	

Glass rod in linear dimensions expands from unity or 1·000000:

32	to 212°	Fah.	1·000861
212	" 392	"	1·000918
392	" 572	"	1·001011

And the length of the following metals at 62° Fah. being 1·000000:

Iron, cast at 212° Fah. = 1·000893—at 662° = 1·003943, fusing-point 1·016389.
Copper, " = 1·001430 " = 1·006347, " 1·024376.
Zinc, " = 1·002480 " = 1·008527, " 1·012621.

84. *For practical or engineering purposes, how are metals ranged in regard to their power of conducting heat?*

In the following order and ratio:—

Copper	being	. . .	1·000
Iron	"	. . .	= ·416
Zinc	"	. . .	= ·405
Tin	"	. . .	= ·338
Lead	"	. . .	= ·200

85. *For practical purposes, as that of retaining heat in pipes, &c., what are the worst conductors?*

Stones, bricks, earthenware, glass, lint, sheep's wool, raw silk, and fur, are successively lower than each other in conducting powers.

86. *What is meant by radiation of heat?*

By radiation of heat is understood the heating effects produced by direct rays from a hot body through space, as light is from that of a luminous body; the diminution of effect being as the square of the distance receded from; hence, if at any given distance a certain power of heat is produced, at twice that distance the power of effect will be one-fourth, and at three times the distance one-ninth, &c.

87. *What is meant by the appellation* specific heat?

Specific heat—formerly capacity for heat—is a term applied to the quantity of caloric any substance can absorb or give out, by undergoing a change of temperature; the amount being determined by relation of quantity which a substance of another kind, as water, absorbs or gives out by a like change. Thus, the quantity of heat required to raise oil two degrees, will only raise water one. Hence, a pound of water at 212° is said to contain twice as much heat, or to have twice the capacity for heat, as that of oil.

The specific heat of	Water	being . .	1·000
" specific heat of	Oil	= . .	0·520
" "	Iron	= . .	0·112
" "	Copper	= . .	0·095
" "	Zinc	= . .	0·093
" "	Mercury	= . .	0·029

88. *How is the amount of effect by an increase of caloric in steam after being separated from the water of formation, estimated?*

It has been ascertained by experiments, that steam to which heat is applied, after being separated from the water of formation, is subject to the same laws of expansion as atmospheric air and gases generally; the increase in volume from unity being 1·375 for 180 degrees of elevated temperature; hence the rule—

To the temperature, both before and after expansion, add the constant number 459, divide the greater sum by the lesser, multiply the quotient by the volume at the lower temperature, and the product is the expanded volume.

Ex.—If the volume of steam produced from water, at 212° Fah., be 1711 times the bulk of

the water from which it is produced, what will be its volume at the temperature of 250·3 degrees, supposing the pressure to be the same in both cases?

$$\frac{250{\cdot}3 + 459}{212 + 459} = \frac{709{\cdot}3}{671} \times 1711 = 1808{\cdot}66.$$

89. *Suppose the safety-valve on a steam-boiler is* 9½ *inches diameter, and loaded with a cylindrical weight of cast-iron* 12 *inches in diameter and* 20 *inches in depth, required the pressure to which the boiler is loaded in pounds per square and circular inch.*

$9{\cdot}5^2 = 90{\cdot}25$ circular inches } in the
$90{\cdot}25 \times {\cdot}7854 = 70{\cdot}88$ square " } valve.

1 cubic inch of cast-iron = ·2608 pounds; sp. gr. 7207.

$12^2 \times {\cdot}7854 \times 20 \times {\cdot}2608 = 589{\cdot}88$ pounds, the weight.

Hence, $589{\cdot}88 \div 70{\cdot}88 = 8{\cdot}3$ pounds per square inch.

And $589.88 \div 90{\cdot}25 = 6{\cdot}5$ pounds per circular inch.

90. *The upper side of an equilibrium-valve is* 10 *inches diameter, and the lower one* 9½ *inches; what force must be exerted to open it, when the steam has a pressure of* 20 *pounds above the atmosphere?*

$10^2 \times .7854 = 78.54$
$9.5^2 \times .7854 = 70.88$ } area of each valve.

20 + 15 = 35 pounds total pressure of steam per square inch.

78·54 × 35 = 2748·9

70·88 × 35 = 2480·8; hence 2748·9 − 2480·8 = 268·1 pounds.

91. *What relation, in regard to capacity, does the cylinder, the sphere, and the cone, bear to the cube?*

If the cube be considered 1;—the cylinder equal ·7854;—the sphere ·5236;—and the cone ·2619. Or, if the cube be the cubic foot which contains 1728 cubic inches:—a cylinder 12 inches diameter, and 12 inches in height, contains 2200 cylindrical inches; a sphere 12 inches diameter contains 3300 spherical inches; and a cone, the base of which is 12 inches, and perpendicular height 12 inches, contains 6600 conical inches.

92. *If the capacity and density of a body is known, how is any other relative capacity or density obtained?*

By the rules of mensuration, and tables of specific gravities.

93. *If the capacity of a cylinder is to be* 9660 *cubic inches, the depth being* 42 *inches, what must be the diameter?*

$$\sqrt{\frac{9660}{42 \times .7854}} = \sqrt{\frac{9660}{32.98}} = 17.12 \text{ inches diam.}$$

94. *Required the weight of any irregular body, which floats in fresh water, and displaces* 2003·75 *cubic inches?*

1 cubic inch of fresh water = ·03617 pounds.

And 2003·75 × .03617 = 72·475 pounds in weight.

95. *A cistern,* 10 *feet diameter and* 3 *feet deep, is capable of containing* 1468·38 *gallons; how much must its depth be augmented, so as to render it capable of containing* 2000 *gallons?*

1468·38 : 3 : : 2000 : 4·087 feet in depth.

96. *The weight of a ball of cast-iron, 9 inches in diameter, is* 100·37 *pounds; what must be the diameter of a leaden ball of equal weight?*

Specific gravity of cast-iron = 7·207
" " lead = 11·352

hence $7207 : 9^3 :: 11{\cdot}352 : \sqrt[3]{466} = 7{\cdot}76$ inches diameter.

97. *What are the general laws of fluids in regard to weight and pressure?*

The weight of a fluid is as the quantity, but the pressure exerted is as the vertical height; hence, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the transverse sectional area of the column.

98. *If a conical vessel whose vertical height is* 3 *feet, and the diameter of its base* 2 *feet, be placed upon the ground, and filled with fresh water, what will be the pressure on the base in pounds?*

Weight of a column of fresh water, 1 inch diameter, and 1 foot in height = ·341 pounds, and $24^2 = 576$, hence $\cdot 341 \times 576 = 589{\cdot}248$ pounds.

99. *Each side of a cubical iron tank in which tallow is kept, measures* 35½ *inches; required to know the number of pounds remaining, when at* 18 *inches in depth—the tallow having been heated sufficient to render it compact as one solid mass.*

Specific gravity of tallow = 942 — 1 cubic inch = ·034 pounds.

Hence, 35·5 × 35·5 = 1260·25 square inches.

And 1260·25 × ·034 × 18 = 771·27 pounds.

100. *A similar tank, with* 23 *inches of oil in depth; how many imperial gallons?*

An imperial gallon = 277·274 cubic inches — 1 cubic inch = ·003607.

Hence, 1260·25 × ·003607 × 23 = 104·55 gallons.

101. *Because of the weight of paddle-wheels in steam-vessels, and the difficulty of properly lubricating the outer end of paddle-shafts, the bearings frequently wear down, and consequently the shafts become not in one direct line; now, when such takes place, how is the proper thickness of lining obtained, or how much must the outer end of shaft*

be raised, so that the shafts may again be brought to their proper lineable position?

Set the engine either at top or bottom stroke; measure the distance between the cranks as near the extremity of length as convenience will admit; turn the engine round to the other extremity of stroke, and then at the same point on the crank take also their distance. Obtain the length of paddle-shaft from face of crank to outer bearing, also the length of crank from centre to that point on its face where their distance between was taken; then say, as the distance from centre of crank-shaft to point where the distance between cranks has been taken, is to the difference of distances between the cranks at top and bottom strokes, so is the length of paddle-shaft to half the thickness of lining required.

Ex.—Suppose the length of a paddle-shaft from face of crank to face of outer bearing equal 16 feet 3 inches, and the length on face of crank from centre of shaft to where the distance between cranks was taken equal 2 feet 8 inches, the difference of distance between crank at top and bottom three-eighths of an inch, what is the outer end of shaft down, and what thickness of

liner will be required under the brass, so as to bring the shafts in a direct line?

16 feet 3 inches = 195 inches, and 2 feet 8 inches = 32 inches.

Hence, 32 : 37·5 : : 195 : 1·676 ÷ 2 = ·838 inches.

102. *What is meant by proper lubrication?*

By proper lubrication is implied a sufficient supply of unguent matter to a revolving or otherwise moving body, whereby to diminish friction, and prevent abrasion by interposition between the moving and stationary surfaces.

103. *What are the common known laws of friction?*

1. When no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together; so that for any two given surfaces of contact there is a constant ratio of the friction to the perpendicular pressure of the surface upon the other.

2. When no unguent is interposed, the amount

of the friction is, in every case, wholly independent of the extent of the surfaces of contact; so that the force with which two surfaces are pressed together being the same, their friction is the same, whatever may be the extent of their surfaces of contact.

3. That the friction of motion is wholly independent of the velocity of the motion.

4. That where unguents are interposed, the amount of friction depends more upon the nature of the unguent, and upon the greater or less abundance of the supply, than upon that of the surfaces in contact. It has been ascertained by experiments, that with a continuous, interposed stratum of hog's-lard and olive-oil, between wood and wood, metal on wood, and metal on metal, in motion, the amount of friction is nearly an equal quantity; but to render an unguent of proper efficiency, the nature of such substances used must be measured by the pressure or weight tending to force those surfaces together.

104. *When, by any mode of measure, it is ascertained that, for condensation of steam, an engine requires* 93 *gallons of water per minute, the num-*

ber of strokes of the engine being 25 per minute, what diameter of pump will be necessary, supposing the pump's length of stroke to be two feet three inches?

1 gallon = 353 circular inches — 2 feet 3 inches = 27 lineal inches.

And $27 \times 25 = 975$; hence $\frac{353 \times 93}{675} = \frac{32829}{675}$ $= \sqrt{48{\cdot}64} = 6{\cdot}97$ inches diameter.

105. *What is any common rule through which to ascertain, by calculation, the proper capacity of a cold-water pump for a stationary condensing engine?*

RULE.—Multiply the square of the cylinder's diameter in inches by the length of the stroke in feet, and by the decimal ·5, the product is the capacity of the pump in cylindrical inches. Or, if the capacity in cylindrical inches be multiplied by ·00284, the product equal the capacity in imperial gallons.

EX.—Suppose an engine with a cylinder 60 inches in diameter, the length of stroke 5½ feet, required the proper capacity for a cold-water pump.

$60^2 \times 5{\cdot}5 = 19800 \times {\cdot}5 = 9900$ cylindrical inches

And $9900 \times {\cdot}00284 = 28{\cdot}116$ imperial gallons } Capacity.

106. *How is the capacity of an air-pump determined for condensing engines?*

RULE.—Multiply the square of the cylinder's diameter in inches by the length of the piston's stroke, also in inches, and by ·142, the product equal the capacity of air-pump in cylindrical inches.

EX.—Required the capacity of air-pump for an engine with a cylinder 45 inches in diameter, and a stroke of four feet; also, what will be the diameter when worked at two-thirds from the centre of the beam or side-levers, half the length of which equal six feet three inches.

$45^2 \times 48 = 97200 \times {\cdot}142 = 13802{\cdot}4$ cylindrical inches capacity.

6 feet 3 inches = 75, and $\frac{75 \times 2}{3} = 50$ inches from centre of beam.

Then 75 : 48 :: 50 : 32 inches, the length of stroke of air-pump.

Hence $\frac{13802{\cdot}4}{32} = \sqrt{431{\cdot}3} = 20{\cdot}76$ inches diameter.

107. *How is the proper weight ascertained whereby to make the rim of the fly-wheel of a rotary engine?*

RULE.—Multiply the diameter of the wheel in feet by the number of revolutions per minute, and by ·0523; divide 2004 times the nominal horse-power of the engine by the square of the product, and the quotient is the weight in hundredweights.

EX.—What must be the weight of a fly-wheel rim for a thirty-horse engine making 19 revolutions per minute, and diameter of the wheel 22 feet.

$22 \times 19 = 418 \times {\cdot}0523 = 21{\cdot}8614$ and $\frac{30 \times 2004}{21{\cdot}8614^2}$ = 126 cwts. weight of the rim.

108. *What is the rule by which to find the proper velocity for the governor of a steam-engine?*

The governor of a steam-engine in the usual form consists of two pendulums suspended from the upper extremity of a vertical axis; and, when made to revolve about that axis, assumes the coni-

cal form, the point of suspension being the apex of the cone, and the distance from centre to centre of the balls the plane of revolution; hence, when a certain expansion of the balls is desired, and a certain given length of pendulum fixed, so that the vertical height of the cone is known, multiply the square root of the height of the cone in inches by 0·31986, and 60 divided by the product equal the proper number of revolutions per minute.

Ex.—Suppose the distance between the centre of suspension and plane of revolution equal 25 inches, required the number of revolutions per minute.

$\sqrt{25} = 5$ and $\cdot 31986 \times 5 = 1{\cdot}5993$, then $60 \div 1{\cdot}5993 = 38$.

109. *How are the various valves in marine engines generally distinguished?*

Names.	Forms.
1. Safety valve . . .	Conical.
2. Stop valve	Do.
3. Inverse valve . . .	Conical or flat.
4. Feed valve . . .	Conical.
5. Throttle valve . .	Oval or rectangular.
6. Blow-through valve .	Conical.

Names.	Forms.
7. Snifting valve . .	Conical.
8. Expansion valve . .	Various.
9. Slide valve . .	Long D, short D, and locomotive.
10. Foot valve . . .	Flat.
11. Delivery or head valve	Do.
12. Escape or relief valve	Conical or flat.
13. Sluice valve . . .	Flat.
14. Kingston valve . .	Cone.

110. *At page* 24, *question* 23, *a rule is given by which to determine the nominal horse-power of condensing engines. How is the nominal horse-power of non-condensing engines estimated?*

RULE.—Multiply the square of the cylinder's diameter in inches by the pressure of the steam in pounds per square inch above the atmospheric pressure, and by the cube root of the stroke in feet, also by ·00106, and the product is the nominal horse-power, when the velocity is 128 times the cube root of the stroke.

EX.—Let the diameter of the cylinder of a high-pressure engine equal 16 inches, the length of stroke 3½ feet, and the pressure of steam 45 pounds per square inch, as indicated by the safety-

valve; required the nominal horse-power of the engine.

$16^2 \times 45 \times \sqrt[3]{3\frac{1}{2}} \times .00106 = 18.3$ horse-power.

111. *What is the difference between high-pressure and non-condensing engines?*

None whatever in principle, merely in technicality; all engines are said to be high-pressure, or on the non-condensing principle, where steam, after useful application, is still of sufficient density or force to overcome atmospheric pressure. At present there are employed usefully only three distinct kinds of engines, viz. condensing, non-condensing, and those in which both principles are combined through the medium of two cylinders of unequal capacities, and steam of high elastic force introduced, terminating by expansion and ultimate condensation, and commonly called double-cylinder engines.

112. *Are locomotive engines estimated in horse-power as other engines, whereby to test their amount of efficiency.*

Locomotive engines may be, and are sometimes estimated in productive effect as other non-condensing engines; but the amount of power is more

frequently compared with the load in tons that an engine is capable of drawing upon a level line at a given velocity.

A rule by which to determine the pressure of steam to draw a certain load, with a given engine, on a level line, being as follows :—To 6 times the weight of engine and tender in tons, add $9\frac{1}{2}$ times the weight of the train in tons; multiply the sum by the circumference of the driving-wheels in inches; divide the product by twice the area of the piston in inches, multiplied by the length of stroke in inches, and the quotient equal the required pressure of steam in pounds per square inch.

Ex.—Suppose a locomotive engine, with two cylinders of 13 inches diameter each, length of stroke 18 inches, diameter of driving-wheels $5\frac{1}{2}$ feet, weight of engine and tender 18 tons, weight of train 167 tons, what pressure of steam will be required, per square inch, to move the same upon a level line, atmospheric resistance not being taken into account?

$$18\times6 = 108$$
$$167\times9\cdot5=1586\cdot5$$
$$+1694\cdot5$$

5·5 feet=66 inches$\times3\cdot1416=$ 207·3$\times$ And

$13^2\times\cdot7854\times2\times36=9556\cdot5)351269\ 85(36\cdot7$ lbs.

113. *How is the resistance of the atmosphere ascertained relative to a railway train?*

The resistance to any flat surface 1 foot square, passing through a still atmosphere at about 1 mile per hour, is ·005 pounds, and the resistance increases as the square of the velocity. Hence, if a train expose an opposing frontage of 20 square feet, at a velocity of 1 mile per hour, $1^2 \times 20 \times \cdot005 = 1$ pound; but, if the velocity be increased to 20 miles per hour, the opposing force on the same surface equal $20^2 \times 20 \times \cdot005 = 40$ pounds.

114. *What is the effect of gravity by a train ascending or descending an inclined plane?*

In ascending any inclined plane, the weight or resistance of the train to traction is augmented by gravity as the rise or incline of the plane is

to the weight; hence, if 1 ton, or 2240 pounds, be the unit of weight, 9½ pounds per ton the unit of traction upon a level line, and 1 in 350 the inclination of the plane, then 2240 ÷ 350 = 6·4 + 9·5 = 15·9 pounds, or the force of traction required upon the incline.

Again, if the train be descending, the force of traction is diminished in an equal ratio, and the train accelerated by gravity; thus, 9·5 — 6·4 = 3·1 pounds, required for traction on the descending plane.

115. *If a railway train be started at a given time, to continue at a known speed, say* 27 *miles per hour, and after* 35 *minutes a despatch train is sent to overtake it, which is to run at the rate of* 33 *miles per hour, how far will the first train have gone when the second overtakes it, and what length of time, from the time of the despatch train starting, will it be when overtaken?*

RULE.—As the difference of the speed of two bodies in motion is to the distance gone by one, so is the motion of the quicker body to the distance or time required; hence—

33 — 27 = 6 and 27 ÷ 60 = ·42 miles per minute, speed of first train.

Then ·42 × 35 = 14·7 and 6 : 14·7 : : 35 : 85·75 miles distant when overtaken.

Again, 6 : 42 : : 35 : 2·45 hours, or 2 hours 27 minutes from the time of second train starting.

116. *Suppose a goods' train to start from a given place or station on a line of railway at a given time, and its rate of continued speed* 20 *miles per hour; also from the opposite end of the line, and at the same time, a passenger train starts, and continues at a uniform speed of* 36 *miles per hour; at what distance from each starting station will the two trains meet, the distance between the two stations being* 212 *miles?*

36 × 20 = 56, and 56 : 212 : : 1 : 3·786 hours, or time of each train in motion before meeting.

3·786 × 36 = 136·296 miles gone over by passenger train.

And 3·786 × 20 = 75·72 miles gone over by goods' train.

117. *What are the meanings of the various*

terms, gravity, specific gravity, centre of gravity, force of gravity, &c.?

Gravity is downward pressure or weight; all bodies possess this property more or less, in proportion with their various degrees of density.

Specific gravity means the comparative density or weight that one body bears to another of equal bulk,—thus, a body of less specific gravity than water, or other fluid, will float upon that fluid; but if of greater specific gravity, will sink.

Centre of gravity is that point in a body or system of bodies, on which, if rested or suspended, the whole will remain in a state of equilibrium or rest; thus, if a wall or other structure be raised perpendicular to the base, it will remain secure while in that state; but if the foundation be not of sufficient solidity, and by degrees allow it to depart so far from its vertical position that the centre at the top exceeds the base at the bottom, the same will fall, unless restricted by cohesion of the parts of which it is composed.

Force of gravity is an accelerated velocity, which heavy bodies acquire in falling freely from a state of rest;—thus, the velocity that a body will acquire in one second of time, equal 32·1666

feet, or in five seconds 32·1666 × 5 = 160·833 feet, &c., the velocity in feet, per second, that a body will acquire in falling through a given space, equal the square root of the product of the time multiplied by 64·3333. Hence, the velocity acquired at the end of 249 feet—$\sqrt{64\cdot3333} \times 240$ = 124·26 feet. Again: the space through which a body will fall in feet, in any given time, equal the product of the square of the time, multiplied by 16·0833. Hence the space a body will pass through in seven seconds 16·0833×72=788·0817 feet.

Force of gravity is also the restrictive cause to a pendulum's motion; consequently its motion at any place is dependent upon the energy of the force of gravity at that place.

Pendulums of the same length vibrate slower the nearer they are brought to the equator, because of the earth's spheroidal form, its polar axis being about twenty-six miles shorter than its equatorial diameter; for which reason, also, gravity is lessened $\frac{1}{289}$th part, the centrifugal force arising from the diurnal motion of the earth being greater at the equator than at the poles.

The measure of the force of gravity in feet,

per second, at any place, is equal to the product of the length of a pendulum that beats seconds; these multiplied by 9·8696; or, if any length of a pendulum be taken in feet, and the time in seconds observed between each of its oscillations, then the length of the pendulum divided by the square of the time in seconds, and the quotient multiplied by 9·8696, the product equal the number of feet, by which gravity will at that place increase the velocity of the descent of a falling body in each second of time.

The length of a pendulum to vibrate seconds, or 60,

At the equator, equal . . .		39·0152	inches.
In the latitude of	London .	39·1393	"
" "	Edinburgh	39·1555	"
" "	Paris . .	39·1285	"
" "	New York	39·1011	"

118. *The length of a seconds pendulum at a given place being known, how is the length of another pendulum obtained, to perform any other number of vibrations in the same time?*

RULE.—Multiply the square root of the known length of pendulum by 60, divide the product by

the required number of vibrations, and the square of the quotient is the length required.

Ex.—What must be the length of a pendulum to make 80 vibrations per minute in the latitude of Edinburgh, the length of seconds pendulum being 39·1555 inches?

$$\frac{\sqrt{39{\cdot}1555 \times 60}}{80} = \frac{375{\cdot}42}{80} = 4{\cdot}63^2 = 21{\cdot}437 \text{ inches.}$$

119. *What is the subsisting ratio between that of a seconds pendulum and gravitating force?*

The space through which a heavy body will fall during the time of one vibration of a pendulum vibrating seconds, is to half the pendulum's length as the square of the circumference of a circle is to the square of its diameter, or as 4·9348 to the whole length; hence, the force of gravity in the latitude of London equal 39·1393 × 4·9348 = 193·1446 inches, or 16 feet 1 inch nearly.

120. *What is meant by centre of oscillation?*

The centre of oscillation is a certain point in a vibrating body into which all its force is collected, and to which, if an obstacle be applied, motion will instantly cease. The most simple means by which to ascertain the centre of oscillation in a

compound pendulum, is to suspend a small ball by a fine thread in front of that in which the centre of oscillation is required, lengthen or shorten the thread until the vibrations of each are alike, then stop both and let them hang freely. Opposite the centre of the ball is the centre of oscillation.

121. *How is gravity affected by motion on descending planes or curved surfaces?*

The force which accelerates the motion of a heavy body on an inclined plane, is to the force of gravity as the sine of the inclination of the plane to the radius, or as the height of the plane to its length.

The velocity acquired by a body in falling from rest through a given height is the same, whether it fall freely or descend on a plane at whatever inclination.

The space through which a body will descend on an inclined plane, is to the space through which it would fall freely in the same time as the sine of the inclination of the plane to the radius.

The velocities which bodies acquire by descending along chords of the same circle, are as the lengths of those chords.

A body descending in a curve suffers no loss of velocity.

122. *By circular motion of bodies there are two effects produced; what are they?*

Centrifugal force and centripetal force.

123. *But what are they? What do the terms imply?*

Centrifugal force implies a tendency that all bodies acquire by accumulated velocity of circular motion to fly off in a tangential line from the centre of revolution, the amount of tendency being as the square of increased velocity of the body in motion; hence the

RULE.—Multiply the square of the number of revolutions per minute by the radius of the circle in feet, by the weight of the body in any given unit of weight, and by ·000331; the product is the centrifugal force in terms of the body's weight.

EX.—Suppose a body weighing 100 pounds, and describing a circle of ten feet radius, and at 300 revolutions per minute, required the centrifugal force

$$300^2 \times 10 \times 100 \times \cdot 000331 = 29 \cdot 790 \text{ lbs.}$$

Centripetal force, on the contrary, is the tendency, by reduced circular motion, to impel the weight toward the centre of rotation; as the balls of the governor of a steam-engine indicate by diminished velocity. When a body in circular motion is retained by means of centripetal force tending toward its centre of rotation, the velocity at every point of revolution is equal to that which it would acquire by falling perpendicularly through half the radius of its orbit. Consequently, if a body revolves uniformly in the circumference of a circle by means of a given centripetal force, the portion of the circumference which it describes in any time is a mean proportional between the diameter of the circle and the space which the body would descend perpendicularly in the same time, and with the same given force continued uniformly.

124. *What is meant by centre of gyration?*

By centre of gyration is understood a certain point in a revolving body, into which the whole momentum of the mass is concentrated, and at which, or from which point, the greatest amount of power or effective force is transmitted; the distance between the centres of suspension and

gyration is a geometrical mean between the centres of gravity and oscillation from the same point; hence, having found the distances of these centres in any proposed case, the square root of their product equal the distance of the centre of gyration.

To find the centre of gyration or circle of greatest transmitting effect in a water-wheel.

RULE.—Multiply by the square of the radius twice the weight of shrouding and buckets, two-thirds the weight of the arms, and the weight of the water; add the whole into one sum, and divide by twice the weight of shrouding and arms, added to the weight of water; the square root of the quotient is the distance of the centre of gyration from the centre of suspension.

EX.—Required the distance of the centre of gyration from the centre of suspension in a water-wheel 22 feet diameter, shrouding and buckets 18 tons, arms 12 tons, and water 10 tons.

$22 \div 2 = 11$ and $11^2 = 121$

Then $18 \times 2 = 36 \times 121 = 4356$

$\frac{2}{3}$ of $12 = 8 \times 121 = 968$

Water $= 10 \times 121 = 1210$

6534

And $\overline{18+12} \times 2 = 60 + 10 = 70$; hence,

$\sqrt{\frac{6534}{70}} = 9{\cdot}6$ feet from the centre of suspension.

125. *What are logarithms?*

Logarithms are artificial numbers which stand for natural numbers, and are so contrived that if the logarithm of one number be added to the logarithm of another, the sum will be the logarithm of the product of these numbers; and if the logarithm of one number be taken from the logarithm of another, the remainder is the logarithm of the latter divided by the former; and also if the logarithm of a number be multiplied by 2, 3, 4, 5, &c., we shall have the logarithm of the square, cube, &c., of that number; and, on the other hand, if divided by 2, 3, 4, 5, &c., we have the logarithm of the square root, cube root, fourth root, &c., of the proposed number; so that with the aid of logarithms, multiplication and division are performed by addition and subtraction, and the raising of powers and extracting of roots are effected by multiplying or dividing by the indices of the powers and roots.

126. *What is meant by mechanic powers?*

By mechanic, or mechanical powers, is commonly understood the application of certain simple machines, by which weight or resistance is overcome at a less expense of power, when time or space is disregarded. Thus a bar or lever resting upon a point or fulcrum at three-fourths distant from one end; it is obvious that the effect is as one to three, or one unit of power will equipoise three of resistance; but if the resistance is to be overcome by the power in any given time, the velocity or space passed through by the power will be three times that to which the resistance has been removed.

127. *How are the mechanic powers usually distinguished.*

They are almost invariably distinguished and arranged for simplicity in the following order, viz. the lever, pulley, inclined plane, wheel and axle, wedge and screw; the three first being considered primary, and the three last secondary, because partaking of the properties of the first by combination.

128. *Relative to mechanics, what is motion?*

Motion, in mechanical language, is generally understood an effect of impulsive force, acting in such a manner as to impart either linear or circular velocity by motive power; thus the piston of a steam-engine is made to produce alternate, rectilinear, or reciprocating motion. In the fly-wheel, through the medium of the crank, is produced uniform circular motion, and by means of cambs, motions to any degree of distortion may be obtained as required.

129. *What are the tendencies by high degrees of velocity, on the bearings of shafts in circular motion?*

Tendency to heat and become enlarged in diameter, whereby lubrication is diminished in efficiency and friction materially augmented.

130. *What is meant by capillary attraction?*

It signifies a property observable in small tubes, thin flat spaces, porous substances, as sponge, cotton wick, worsted threads, &c., of raising water or other fluids above the natural level; hence the application of the principle for obtaining a continued supply of lubricating fluid between surfaces

in motion, by a syphon-form of worsted threads, one end of which is immersed in oil, the other being inserted and supported by the tube through which the fluid is conducted.

131. *In speaking of metals, as gun-metal, brass, bronze, &c., why are they designated alloys?*

Because those metals are composed of two or more having a chemical affinity for each other, and hence said to be an alloy, or combined mixture.

Proportions of Metals for the production of various Alloys.

Machinery	copper 16	tin 2½	zinc ½
Tough brass	copper 10	tin 1½	zinc 1½
Gun metal	copper 11	tin 2	—
Bell metal	copper 16	tin 5	—
Spelter solder, for iron	copper 1	—	zinc 1
" harder	brass 6	tin 1	zinc 1
Solder for copper	brass 8	—	zinc 1
Tinman's solder	lead 2	tin 1	—
A metal that expands in cooling	lead 9	antimony 2	bismuth 1

Table exhibiting the Temperatures and Volumes of Steam generated under different pressures.

Pressure in lbs. per square inch, atmospheric pressure included.	Temperature in degrees of Fahrenheit.	Volumes of steam compared with the volume of water.	Cubic inches of water in a cubic foot of steam.	Pressure in lbs. per square inch, atmospheric pressure included.	Temperature in degrees of Fahrenheit.	Volumes of steam compared with the volume of water.	Cubic inches of water in a cubic foot of steam.
15	213·0	1669	1·035	48	279.7	573	3·015
16	216·4	1572	1·099	49	281·0	562	3·074
17	219·6	1487	1·162	50	282·3	552	3·130
18	222·6	1410	1·226	51	283·6	542	3·188
19	225·6	1342	1·287	52	284·8	532	3·248
20	228·3	1280	1·350	53	286·0	523	3·304
21	231·0	1224	1·411	54	287·2	514	3·361
22	233·6	1172	1·474	55	288·4	506	3·415
23	236·1	1125	1·536	56	289·6	498	3·469
24	238·4	1082	1·597	57	290·7	490	3·526
25	240·7	1042	1·658	58	291·9	482	3·585
26	243·0	1005	1·719	59	293·0	474	3·645
27	245·1	971	1·779	60	294·1	467	3·700
28	247·2	939	1·840	61	294·9	460	3·756
29	249·2	909	1·910	62	295·9	453	3·814
30	251·2	882	1·959	63	297·0	447	3·865
31	253·1	855	2·021	64	298·1	440	3·927
32	255·0	831	2·079	65	299·1	434	3·981
33	256·8	808	2·138	66	300·1	428	4·037
34	258·6	786	2·198	67	301·2	422	4·094
35	260·3	765	2·258	68	302·2	417	4·148
36	262·0	746	2·316	69	303·2	411	4·204
37	263·7	727	2·376	70	304·2	406	4·256
38	265·3	710	2·433	71	305·1	401	4·309
39	266·9	698	2·493	72	306·1	396	4·363
40	268·4	677	2·552	73	307·1	391	4·419
41	269·9	662	2·610	74	308·0	386	4·476
42	271·4	647	2·670	75	308·9	381	4·535
43	272·9	634	2·725	76	309·9	377	4·583
44	274·3	620	2·787	77	310·8	372	4·645
45	275·7	608	2·842	78	311·7	368	4·695
46	277·1	596	2·899	79	312·6	364	4·747
47	278·4	584	2·958	80	313·5	359	4·812

Table by which to ascertain the amount of lap necessary on the steam side of a slide-valve to cut the steam off at various fractional parts of the stroke

To cut the steam off, after the piston has passed through						
$\frac{1}{2}$	$\frac{7}{12}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$	$\frac{11}{12}$
of its stroke. Multiply the given stroke of the valve by						
·354	·323	·289	·250	·204	·177	·144
and the product is the lap of the valve in terms of the stroke.						

Example.—Required the lap necessary to cut the steam off at the end of five-sixths of the stroke, the stroke of the valve being twelve inches, and without lead. $204 \times 12 = 2{\cdot}448$ inches.

As lead is not taken into account because of different quantities being required to different applications of the steam-engine, subtract from the lap half the lead; the remainder is the lap required. Thus, suppose the lead equal $\cdot 25 \div 2 = \cdot 125$ and $2{\cdot}448 - \cdot 125 = 2{\cdot}323$ inches, the lap with one-fourth inch of lead as given.

Table of the Mean Elastic Force of Steam in pounds per square inch, at various grades of Expansion.

Initial density of the steam in lbs. per square inch.	Dense steam cut off after the piston has passed through the following fractional parts of the stroke:						
	1/5	1/4	2/5	1/2	3/5	3/4	4/5
Atmospheric pressure not included. 9	4·69	5·37	6·89	7·62	8·13	8·67	8·80
10	5·22	5·97	7·67	8·46	9·03	9·64	9·78
11	5·74	6·56	8·43	9·31	9·94	10·60	10·76
12	6·26	7·16	9·19	10·16	10·84	11·57	11·74
13	6·78	7·75	9·96	11·01	11·75	12·53	12·72
14	7·31	8·53	10·73	11·85	12·65	13·49	13·97
15	7·83	8·95	11·49	12·69	13·55	14·46	14·68
16	8·35	9·54	12·26	13·54	14·46	15·42	15·66
17	8·87	10·14	13·03	14·39	15·36	16·38	16·63
18	9·39	10·74	13·79	15·24	16·27	17·35	17·61
19	9·92	11·33	14.56	16·81	17·17	18·31	18·59
20	10·44	11·93	15·33	16·93	18·07	19·28	19·57
25	13·04	14·91	19·16	21·16	22·59	24·09	24 46
30	15·65	17·89	22·99	25·39	27·11	28·91	29·35
35	18·26	20·88	26·83	29·63	31·63	33·73	34·24
40	20·87	23·86	30·66	33·86	36·15	38·55	39·14
45	23·48	26·84	34 88	38·09	40·66	43·37	44·03
50	26·09	29·82	38·32	42·33	45·18	48·19	48·92

Example.—If dense steam be admitted to the cylinder of an engine at a pressure of 17 pounds per square inch, and cut off when the piston has moved through two-fifths of the stroke, the mean elastic pressure during the whole stroke will be 13·03 pounds per square inch, as obtained by initial density and expansive force.

Table by which to find the relative state of Piston and Exhaust after Expansion.

Cover on the exhausting side of the valve in parts of the length of its stroke.	Steam cut off at 1-3d from the end of the stroke.		Steam cut off at 1-4th from the end of the stroke.		Steam cut off at 1-6th from the end of the stroke		Steam cut off at 1-8th from the end of the stroke.	
	Distance of the piston from the end of its stroke, when the exhausting-port before it is shut (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port behind it is opened (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port before it is shut (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port behind it is opened (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port before it is shut (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port behind it is opened (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port before it is shut (in parts of the stroke.)	Distance of the piston from the end of its stroke, when the exhausting-port behind it is opened (in parts of the stroke.)
1-8th	·178	·033	·143	·019	·109	·008	·093	·004
1-16th	·130	·060	·100	·040	·171	·022	·058	·015
1-32d	·118	·073	·085	·051	·058	·033	·043	·028
0	·029	·092	·067	·067	·043	·043	·033	·033

Example from the Table.—Suppose an engine with a stroke of six feet, or 72 inches, and the steam cut off when the piston is one-third from the end of its stroke, the cover on the exhaust side of the valve being 1-32d of its stroke, the relative positions will be the following:—

In a line with 1-32d and under 1-3d is ·118 and ·073; therefore $·118 \times 72 = 8·136$ inches the piston is from the end of the stroke, when the exhausting-port before the piston is shut, and $·073 \times 72 = 5·256$ inches the piston is from the end of the stroke, when the exhausting-port behind it is open

Table of Cylinders, with proportionate strokes for Steam-engines of nominal horse-power; the dense steam for Condensing Engines being seven pounds per square inch.

Stationary Condensing Engines.			Marine Condensing Engines.			High-pressure, or Non-condensing Engines.				
Horse-power.	Diameter of cylinders in inches.	Proportionate strokes in feet.	Horse-power.	Diameter of cylinders in inches.	Proportionate strokes in feet.	Horse-power.	Diameter of cylinders in inches, the force of the dense steam per square inch being 25 lbs.	30 lbs.	40 lbs.	50 lbs.
2	9	1¾	10	20	2	1	3¾	3½	3	2¾
3	11	2	12	21½	2	1½	4½	4¼	3⅞	3½
4	12	2¼	15	23½	2¼	2	5¼	4¾	4¼	3¾
5	13½	2½	16	24½	2½	2½	5¾	5⅜	4⅞	4¼
6	14½	2¾	18	25¼	2½	3	6¼	6	5	4½
8	16½	3	20	26½	2½	3½	6¾	6¼	5½	4⅞
10	18	3¼	25	28½	3	4	7½	6⅞	6	5¼
12	19½	3½	30	31½	3	4½	7¾	7⅛	6¼	5⅝
14	21	3½	35	33½	3¼	5	8¼	7½	6½	5⅞
15	21½	3¾	40	36½	3¼	5½	8½	7⅞	6¾	6⅛
16	22	4	45	37½	3½	6	9	8¼	7	6½
18	23	4¼	50	39½	3½	6½	9¼	8⅜	7¼	6⅝
20	24½	4½	55	40½	4	7	9¾	9	7¾	6¾
22	25¼	4½	60	43	4	7½	10	9¼	8	7¼
24	26½	4¾	65	44	4	8	10½	9¾	8¼	7½
25	26¾	5	70	46	4¼	8½	10¾	9⅞	8½	7⅞
26	27	5	75	46¾	4½	9	11⅛	10¼	8¾	7⅞
28	27½	5½	80	48	4½	10	11¾	11	9¼	8½
30	28½	5½	85	49	4¾	11	12¼	11⅜	9¾	8¾
35	30½	5¾	90	50	4¾	12	13	12	10½	9¼
40	32½	6	95	52	4¾	13	13¼	12¼	10⅝	9⅞
45	34¼	6	100	52½	5	14	14	12¾	11¼	10
50	36	6¼	110	55	5	15	14⅝	13⅛	11⅝	10¼
55	37½	6¼	115	56¼	5	16	15	13¾	12	10½
60	39	6½	120	57	5½	17	15¼	14	12½	10¾
65	40½	6½	125	58	5½	18	15¾	14½	12¾	11¼
70	41½	7	130	59	5½	19	16¼	14¾	13¼	11½
75	43	7	135	60	5¾	20	16¾	15¼	13½	11¾
80	44	7¼	140	61	5¾	25	18½	17¼	15	13¼
85	45¼	7½	145	62	5¾	30	20¼	19¾	16¼	14½
90	46	8	150	62½	6	35	21½	20¼	17¼	15½
95	47¼	8	175	67½	6	40	23	21⅜	18¼	16¼
100	48½	8	200	71½	6½	Quantity of water for feed in gallons per minute to each horse-power, equal		·45	·5	·61	·72
110	51	8	250	79½	6½						
120	52¼	8½	260	81	6½						
130	54¼	9	270	81¾	7						
140	56	9	280	83	7						

Table of Nominal Velocities for the Pistons of Steam-engines, with given length of strokes.

Stationary Condensing Engines.			Marine Engines.			High-pressure, or Non-condensing Engines.		
Length in feet and in.	Num. per min.	Velocity in feet per min.	Length in feet and in.	Num. per min.	Velocity in feet per min.	Length in feet and in.	Number per minute.	Velocity in feet per min.
1 9	46	161	2 0	42	168	1 0	80	160
2 0	42	168	2 3	39½	177⅜	1 3	70	175
2 3	38	171	2 6	38	190	1 6	62	186
2 6	35	175	3 0	32	192	1 9	55	192½
2 9	32	176	3 3	29¾	193⅜	2 0	50	200
3 0	30	180	3 6	27¾	194¼	2 3	46	207
3 3	28½	185¼	4 0	24½	196	2 6	42½	212½
3 6	27	189	4 3	23½	199¾	2 9	39½	217¼
3 9	26	195	4 6	22½	202½	3 0	37	222
4 0	25	200	4 9	21½	204¼	3 3	35	228½
4 3	24	204	5 0	21	210	3 6	33	231
4 6	23	207	5 6	19½	214½	3 9	31	232½
5 0	21½	215	5 9	19	218½	4 0	29½	236
5 6	20	220	6 0	18½	222	4 6	27	243
6 0	19	228	6 6	17¼	224¼	5 0	24¾	247½
7 0	17½	245	7 0	16½	231	5 6	23	253
8 0	16	256	7 6	15½	232½	6 0	22	254

Table of Decimal Equivalents to Fractional Parts of Lineal Measures.

One inch, the integer or whole number.

·9375 = 15/16 and 1/16	·5625 = 9/16 and 1/16	·25 = 1/4
·875 = 7/8	·5 = 1/2	·1875 = 3/16 and 1/16
·8125 = 13/16 and 1/16	·4375 = 7/16 and 1/16	·125 = 1/8
·75 = 3/4	·375 = 3/8	·0625 = 1/16
·6875 = 11/16 and 1/16	·3152 = 5/16 and 1/16	·03125 = 1/32
·625 = 5/8		

One foot, or 12 inches the integer.

·9166 = 11 inches.	·4166 = 5 inches.	·0625 = 3/4 of inch.
·6338 = 10 "	·3333 = 4 "	·05208 = 5/8 "
·75 = 9 "	·25 = 3 "	·04166 = 1/2 "
·6666 = 8 "	·1666 = 2 "	·03125 = 3/8 "
·5833 = 7 "	·0833 = 1 "	·02083 = 1/4 "
·5 = 6 "	·07291 = 7/8 "	·1041 = 1/8 "

Table of Approximate Numbers, for various purposes.

Diameter of a circle	×	3·1416	= the circumference.
Circumference "	×	·31831	= the diameter.
Diameter "	×	·8862	= the side of an equal square.
Side of a square.....	×	1·128	= the diameter of an equal circle.
Square of diameter	×	·7854	= the area of a circle.
Square root of area	×	1·12837	= the diameter of equal circle.
Square of the diameter of a sphere	×	3·1416	= convex surface.
Cube of ditto.....	×	·5236	= solidity.
Diameter of a sphere	×	·806	= dimensions of equal cube.
Diameter of a sphere	×	·6667	= length of equal cylinder.
Square inches.....	×	·00695	= square feet.
Cubic inches.....	×	·00058	= cubic feet.
Cubic feet.....	×	·03704	= cubic yards
Cylindrical inches...	×	·0004546	= cubic feet.
Cylindrical feet	×	·02909	= cubic yards.
Cubic inches.....	×	·003607	= imperial gallons.
Cubic feet.....	×	·6232	= "
Cylindrical inches...	×	·002832	= "
Cylindrical feet	×	4·895	= "
183·346 circular inches.....			= 1 square foot.
2200 cylindrical inches.....			= 1 cubic foot.
Avoirdupois pounds	×	·009	= cwts.
Avoirdupois pounds	×	·00045	= tons.
Lineal feet.....	×	·00019	= English statute miles.
Lineal yards.....	×	·000568	= "

Table of the Circumferences and Areas of Circles, advancing by eighths and tenths.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
1 inch	3·1416	·7854	·375	10·6029	8·9462
·1	3·4557	·9503	·4	10·6814	9·0792
·125	3·5343	·9940	·5	10·9956	9·6211
·2	3·7699	1·1309	·6	11·3097	10·1787
·25	3·9270	1·2271	·625	11·3883	10·3206
·3	4·0840	1·3273	·7	11·6239	10·7521
·375	4·3197	1·4848	·75	11·7810	11·0446
·4	4·3982	1·5393	·8	11·9380	11·3411
·5	4·7124	1·7671	·875	12·1737	11·7932
·6	5·0265	2·0106	·9	12·2522	11·9459
·625	5·1051	2·0739	4 inches	12·5664	12·5664
·7	5·3407	2·2698	·1	12·8805	13·2025
·75	5·4978	2·4052	·125	12·9591	13·3640
·8	5·6548	2·5446	·2	13·1947	13·8544
·875	5·8905	2·7611	·25	13·3518	14·1862
·9	5·9690	2·8352	·3	13·5088	14·5220
2 inches	6·2832	3·1416	·375	13·7445	15·0331
·1	6·5973	3·4636	·4	13·8230	15·2053
·125	6·6759	3·5465	·5	14·1372	15·9043
·2	6·9115	3·6013	·6	14·4513	16·6190
·25	7·0686	3·9760	·625	14·5299	16·8001
·3	7·2256	4·1547	·7	14·7655	17·3494
·375	7·4613	4·4302	·75	14·9226	17·7205
·4	7·5398	4·5239	·8	15·0796	18·0956
·5	7·8540	4·9087	·875	15·3133	18·6655
·6	8·1681	5·3093	·9	15·3938	18·8574
·625	8·2467	5·4119	5 inches	15·7080	19·6350
·7	8·4823	5·7255	·1	16·0221	20·4282
·75	8·6394	5·9395	·125	16·1007	20·6290
·8	8·7964	6·1575	·2	16·3363	21·2372
·875	9·0321	6·4918	·25	16·4934	21·6475
·9	9·1106	6·6052	·3	16·6504	22·0618
3 inches	9·4248	7·0686	·375	16·8861	22·6907
·1	9·7389	7·5476	·4	16·9646	22·9022
·125	9·8175	7·6699	·5	17·2788	23·7583
·2	10·0531	8·0424	·6	17·5929	24·6301
·25	10·2102	8·2957	·625	17.6715	24·8505
·3	10·3672	8·5580	·7	17·9071	25·5176

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·75	18·0642	25·9672	·2	25·7611	52·8102
·8	18·2212	26·4208	·25	25·9182	53·4562
·875	18·4569	27·1085	·3	26·0752	54·1062
·9	18·5354	27·3397	·375	26·3109	55·0885
6 inches	18·8496	28·2744	·4	26·3894	55·4178
·1	19·1637	29·2247	·5	26·7036	56·7451
·125	19·2423	29·4647	·6	27·0177	58·0881
·2	19·4779	30·1907	·625	27·0963	58·4264
·25	19·6350	30·6796	·7	27·3319	59·4469
·3	19·7920	31·1725	·75	27·4890	60·1321
·375	20·0277	31·9192	·8	27·6460	60·8213
·4	20·1062	32·1699	·875	27·8817	61·8625
·5	20·4204	33·1831	·9	27·9602	62·2115
.6	20·7345	34·2120	9 inches	28·2744	63·6174
·625	20·8131	34·4717	·1	28·5885	65·0389
·7	21·0487	35·3566	·125	28·6671	65·3968
·75	21·2058	35·7847	·2	28·9027	66·4762
·8	21·3628	36·3168	·25	29·0598	67·2007
·875	21·5985	37·1224	·3	29·2168	67·9292
·9	21·6770	37·3928	·375	29·4525	69·0293
7 inches	21·9912	38·4846	·4	29·5310	69·3979
·1	22·3053	39·5920	·5	29·8452	70·8823
·125	22·3839	39·8713	·6	30·1593	72·3824
·2	22·6195	40·7150	·625	30·2379	72·7599
·25	22·7766	41·2825	·7	30·4735	73·8982
·3	22·9336	41·8539	·75	30·6306	74·6620
·375	23·1693	42·7184	·8	30·7876	75·4298
·4	23·2478	43·0085	·875	31·0233	76·5887
·5	23·5620	44·1787	·9	31·1018	76·9770
·6	23·8761	45·3647	10inches	31·4160	78·5400
·625	23·9547	45·6636	·1	31·7301	80·1186
·7	24·1903	46·5663	·125	31·8087	80·5157
·75	24·3474	47·1730	·2	32·0443	81·7130
·8	24·5044	47·7837	·25	32·2014	82·5160
·875	24·7401	48·7070	·3	32·3580	83·3280
·9	24·8186	49·0168	·375	32·5941	84·5409
8 inches	25·1328	50·2656	·4	32·6726	84·9488
·1	25·4469	51.5300	·5	32·9868	86·5903
·125	25·5255	51·8486	·6	33·3009	88·2475

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·625	33·8795	88·6643	·1	41·1549	134·7824
·7	33·6150	89·9204	·125	41·2338	135·2974
·75	33·7722	90·7627	·2	41·4691	136·8480
·8	33·9292	91·6091	·25	41·6262	137·8867
·875	34·1649	92·8858	·3	41·7832	138·9294
·9	34·2434	93·3133	·375	42·0189	140·5007
11 inches	34·5576	95·0334	·4	42·0974	141·0264
·1	34·8717	96·7691	·5	42·4116	143·1391
·125	34·9503	97·2053	·6	42·7257	145·2675
·2	35·1859	98·5205	·625	42·8043	145·8021
·25	35·3430	99·4021	·7	43·0399	147·4117
·3	35·5010	100·2877	·75	43·1970	148·4896
·375	35·7357	101·6234	·8	43·3540	149·5715
·4	35·8142	102·0705	·875	43·5897	151·2017
·5	36·1284	103·8691	·9	43·6682	151·7471
·6	36·4425	105·6834	14 inches	43·9824	153·9384
·625	36·5211	106·1394	·1	44·2965	156·1453
·7	36·7567	107·5134	·125	44·3751	156·6995
·75	36·9138	108·4342	·2	44·6107	158·3680
·8	37·0708	109·3590	·25	44·7676	159·4852
·875	37·3065	110·7536	·3	44·9248	160·6064
·9	37·3840	111·2204	·375	45·1605	162·2956
12 inches	37·6992	113·0976	·4	45·2390	162·8605
·1	38·0133	114·9904	·5	45·5532	165·1303
·125	38·0919	115·4660	·6	45·8678	167·4158
·2	38·3275	116·8989	·625	45·9459	167·9896
·25	38·4846	117·8590	·7	46·1815	169·7179
·3	38 6416	118·8231	·75	46·3386	170·8735
·375	38·8773	120·2766	·8	46·4956	172·0340
·4	38·9558	120·7631	·875	46·7313	173·7820
·5	39·2700	122·7187	·9	46·8098	174·3666
·6	39·5841	124·6901	15 inches	47·1240	176·7150
·625	39·6627	125·1834	·1	47·4381	179·0790
·7	39·8983	126·6771	·125	47·5167	179·6725
·75	40·4554	127·6765	·2	47·7523	181·4588
·8	40·2124	128·6799	·25	47·9094	182·6545
·875	40·4481	130·1923	·3	48·0664	183·8542
·9	40·5266	130·6984	·375	48·3021	185·6612
13 inches	40·8418	132·7326	·4	48·3806	186·2654

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·5	48·6948	188·6923	·9	56·2346	251·6500
·6	49·0089	191·1349	18 inches	56·5488	254·4696
·625	49·0875	191·7480	·1	56·8629	257·3048
·7	49·3231	193·5932	·125	56·9415	258·0161
·75	49·4082	194·8282	·2	57·1771	260·1558
·8	49·6372	196·0672	·25	57·3342	261·5872
·875	49·8729	197·9330	·3	57·4912	263·0226
·9	49·9514	198·5569	·375	57·7269	265·1829
16 inches	50·2656	201·0624	·4	57·8054	265·9050
·1	50·5797	203·5835	·5	58·1196	268·8031
·125	50·6583	204·2162	·6	58·4337	271·7169
·2	50·8939	206·1209	·625	58·5123	272·4479
·25	51·0510	207·3946	·7	58·7479	274·6465
·3	51·2080	208·6723	·75	58·9056	276·1171
·375	51·4437	210·5976	·8	59·0620	277·5917
·4	51·5224	211·1411	·875	59·2977	279·8110
·5	51·8361	213·8251	·9	59·3763	280·5527
·6	52·1505	216·4248	19 inches	59·6904	283·5294
·625	52·2291	217·0772	·1	60·0045	286·5217
·7	52·4647	219·0402	·125	60·0831	287·2723
·75	52·6218	220·3537	·2	60·3187	289·5298
·8	52·7788	221·6712	·25	60·4758	291·0397
·875	53·0145	223·6549	·3	60·6328	292·5536
·9	53·0930	224·3180	·375	60·8685	294·8312
17 inches	53·4072	226·9086	·4	60·9470	295·5931
·1	53·7213	229·6588	·5	61·2612	298·6483
·125	53·7999	230·3308	·6	61·5753	301·7192
·2	54·0355	232·3527	·625	61·6539	302·4894
·25	54·1926	233·7055	·7	61·8895	304·8060
·3	54·3496	235·4623	·75	62·0466	306·3550
·375	54·5853	237·1049	·8	62·2036	307·9082
·4	54·6038	237·7877	·875	62·4393	310·2452
·5	54·9780	240·5287	·9	62·5178	311·0252
·6	55·2921	243·2855	20 inches	62·8320	313·1620
·625	55·3707	243·9771	·1	63·1461	317·3094
·7	55·6068	246·0579	·125	63·2247	318·0992
·75	55·7684	247·4500	·2	63·4603	320·4746
·8	55·9204	248·8461	.25	63·6174	322·0630
·875	56·1561	250·9475	·3	63·7744	323·6554

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·375	64·0101	328·0514	·8	71·6284	408·2828
·4	64·0886	326·3520	·875	71·8641	410·9728
·5	64·4028	330·0643	·9	71·9426	411·8716
·6	64·7161	333·2923	23 inches	72·2568	415·4766
·625	64·7955	334·1018	·1	72·5709	419·5972
·7	65·0311	336·5360	·125	72·6495	420·0049
·75	65·1882	338·1637	·2	72·8851	422·7386
·8	65·3452	339·7954	·25	73·0422	424·5577
·875	65·5809	342·2508	·3	73·1992	426·3858
·9	65·6594	343·0705	·375	73·4349	429·1352
21 inches	65·9736	346·3614	·4	73·5134	430·0536
·1	66·2870	349·6679	·5	73·8276	433·7371
·125	66·3663	350·4970	·6	74·1417	437·4363
·2	66·6012	352·9901	·625	74·2203	438·3636
·25	66·7590	354·6571	·7	74·4559	441·1511
·3	66·7916	356·3281	·75	74·6130	443·1149
·375	67·1517	358·8419	·8	74·7680	444·8819
·4	67·2930	359·6817	·875	75·0057	447·6992
·5	67·5444	363·0511	·9	75·0882	448·6283
·6	67·8585	366·4362	24 inches	75·3984	452·3904
·625	67·9371	367·2849	·1	75·7125	456·1681
·7	68·1727	369·8370	·125	75·7911	457·1150
·75	68·3298	371·5432	·2	76·0267	459·9616
·8	68·4868	373·2584	·25	76·1838	461·8642
·875	68·7225	375·8261	·3	76·3408	463·7708
·9	68·8010	376·6856	·375	76·5765	466·6380
22 inches	69·1152	380·1336	·4	76·6523	467·5957
·1	69·4923	383·5972	·5	76·9692	471·4363
·125	69·5079	384·4655	·6	77·2833	475·2926
·2	69·7435	387·0765	·625	77·3619	476·2592
·25	69·9006	388·8220	·7	77·5975	479·1646
·3	70·0576	390·5751	·75	77·7546	481·1065
·375	70·2933	393·2031	·8	77·9116	483·0524
·4	70·3718	394·0823	·875	78·1473	485·9785
·5	70·6860	397·6087	·9	78·2258	486·9558
·6	71·0001	401·1509	25 inches	78·5400	490·8750
·625	71·0787	402·0388	·1	78·8541	494·8098
·7	71·3143	404·7087	·125	78·9327	495·7960
·75	71·4714	406·4935	·2	79·1683	498·7604

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·25	79·3254	500·7415	·7	87·0223	602·6295
·3	79·4824	502·7266	·75	87·1794	604·8070
·375	79·7181	505·7117	·8	87·3364	606·9885
·4	79·7966	506·7086	·875	87·5721	610·2680
·5	80·8108	510·7063	·9	87·6506	611·3632
·6	80·4249	514·7196	28inches	87·9648	615·7536
·625	80·5035	515·7255	·1	88·2789	620·1596
·7	80·7391	518·7488	·125	88·3575	621·2636
·75	80·8962	520·7692	·2	88·5931	624·5814
·8	81·0532	522·7936	·25	88·7502	626·7982
·875	81·2889	525·8375	·3	88·9072	629·0190
·9	81·3674	526·8541	·375	89·1429	632·3574
26inches	81·6816	530·9304	·4	89·2214	633·4722
·1	81·9976	535·4223	·5	89·5356	637·9411
·125	82·0743	536·0477	·6	89·8497	642·4257
·2	82·3099	539·1290	·625	89·9283	643·5494
·25	82·4670	541·1896	·7	90·1639	646·9261
·3	82·6240	543·2533	·75	90·3210	649·1821
·375	82·8597	546·3561	·8	90·4780	651·4421
·4	82·9382	547·3923	·875	90·7137	654·8395
·5	83·2524	551·5471	·9	90·7922	655·9739
·6	83·5665	555·7176	29inches	91·1064	660·5214
·625	83·6451	556·7627	·1	91·4205	665·0845
·7	83·8007	559·9038	·125	91·4991	666·2278
·75	84·0378	562·0027	·2	91·7347	669·6634
·8	84·1948	564·1056	·25	91·8918	671·9587
·875	84·4305	567·2674	·3	92·0488	674·2580
·9	84·5090	568·3232	·375	92·2845	677·7143
27inches	84·8232	572·5566	·4	92·3630	678·8683
·1	85·1373	576·8056	·5	92·6772	683·4943
·125	85·2159	577·8703	·6	92·9913	688·1360
·2	85·4515	581·0703	·625	93·0699	689·2989
·25	85·6086	583·2085	·7	93·3054	692·7934
·3	85·7656	585·3507	·75	93·4626	695·1280
·375	86·0013	588·5714	·8	93·6196	697·4666
·4	86·0798	589·6469	·875	93·8553	700·9817
·5	86·3940	593·9587	·9	93·9338	702·1554
·6	86·7081	598·2863	30inches	94·2480	706·8600
·625	86·7867	599·3706	·1	94·5621	711·5802

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·125	94·6407	712·7627	·6	102·4161	884·6917
·2	94·8763	716·3162	·625	102·4947	835·9724
·25	95·0334	718·6900	·7	102·7303	839·8203
·3	95·1904	721·0678	·75	102·8874	842·3905
·375	95·4261	724·6419	·8	103·0444	844·9647
·4	95·5046	725·8352	·875	103·2801	848·8333
·5	95·8188	730·6183	·9	103·3586	850·1248
·6	96·1329	735·4171	33 inches	103·6728	855·3006
·625	96·2115	736·6193	·1	103·9869	860·4920
·7	96·4471	740·2316	·125	104·0653	861·7904
·75	96·6842	742·6447	·2	104·3011	865·6992
·8	96·7612	745·0618	·25	104·4580	868·3068
·875	96·9969	748·6948	·3	104·6151	870·9222
·9	97·0754	749·9077	·375	104·8507	874·8477
31 inches	97·3896	754·7694	·4	104·9294	876·1608
·1	97·7037	759·6467	·5	105·2436	881·4151
·125	97·7828	760·8685	·6	105·5577	886·6851
·2	98·0179	764·5397	·625	105·6361	888·0080
·25	98·1750	766·9921	·7	105·8719	891·9709
·3	98·3320	769·4485	·75	106·0288	894·6176
·375	98·5677	773·1404	·8	106·1860	897·2728
·4	98·6452	774·3729	·875	106·4215	901·2567
·5	98·9604	779·3131	·9	106·5002	902·5895
·6	99·2745	784·2689	34 inches	106·8144	907·9224
·625	99·3531	785·5104	·1	107·1285	913·2709
·7	99·5887	789·2406	·125	107·2069	914·6084
·75	99·7458	791·7322	·2	107·4272	918·6352
·8	99·9028	794·2278	·25	107·5995	921·3211
·875	100·1355	797·9786	·3	107·7568	924·4115
·9	100·2170	799·2308	·375	107·9922	928·0584
32 inches	100·5312	804·2496	·4	108·0718	929·4109
·1	100·8453	809·2840	·5	108·3852	934·8223
·125	100·9240	810·5450	·6	108·6593	940·2494
·2	101·1595	814·3341	·625	108·7779	941·6066
·25	101·3166	816·8650	·7	109·0352	945·6922
·3	101·4736	819·3999	·75	109·1703	948·4174
·375	101·7093	823·2096	·8	109·3076	951·1508
·4	101·7478	824·4815	·875	109·5630	955·2529
·5	102·1020	829·5787	·9	109·6418	956·6250

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
35 inches	109·9560	962·1150	·4	117·4958	1098·5862
·1	110·2701	967·6206	·5	117·8100	1104·4687
·125	110·3484	968·9973	·6	118·1241	1110·3671
·2	110·5843	973·1420	·625	118·2027	1111·8441
·25	110·7411	975·9063	·7	118·4383	1116·2811
·3	110·8984	978·6790	·75	118·5954	1119·2440
·375	111·1338	982·8400	·8	118·7524	1122·2109
·4	111·2126	984·2318	·875	118·9881	1126·6685
·5	111·5268	989·8003	·9	119·0666	1128·1564
·6	111·8419	995·3845	38 inches	119·3808	1134·1176
·625	111·9192	996·7807	·1	119·6949	1140·0946
·7	112·1551	1000·9843	·125	119·7735	1141·5911
·75	112·3119	1003·7879	·2	120·0091	1146·0870
·8	112·4692	1006·6000	·25	120·1662	1149·0892
·875	112·7046	1010·8197	·3	120·3232	1152·0954
·9	112·7834	1012·2313	·375	120·5589	1156·6119
36 inches	113·0976	1017·8784	·4	120·6374	1158·1194
·1	113·4117	1023·5411	·5	120·9516	1164·1591
·125	113·4903	1024·9592	·6	121·2657	1170·2145
·2	113·7259	1029·2195	·625	121·3443	1171·7309
·25	113·8830	1032·0646	·7	121·5799	1176·2857
·3	114·0400	1034·9131	·75	121·7370	1179·3271
·375	114·2757	1039·1946	·8	121·8940	1182·3725
·4	114·1542	1040·6235	·875	122·1297	1186·9480
·5	114·6684	1046·3491	·9	122·2082	1188·4651
·6	114·9825	1052·0904	39 inches	122·5224	1194·5934
·625	115·0611	1053·5281	·1	122·8365	1200·7273
·7	115·2967	1057·8474	·125	122·9151	1202·2633
·75	115·4538	1060·7317	·2	123·1507	1206·8770
·8	115·6108	1063·6200	·25	123·3078	1209·9577
·875	115·8465	1067·9599	·3	123·4648	1213·0424
·9	115·9250	1069·4084	·375	123·7005	1217·6768
37 inches	116·2392	1075·2126	·4	123·7790	1219·2243
·1	116·5533	1081·0324	·5	124·0932	1225·4203
·125	116·6319	1082·4898	·6	124·4073	1231·6328
·2	116·8675	1086·8679	·625	124·4859	1233·1884
·25	117·1246	1089·7915	·7	124·7215	1237·8610
·3	117·1816	1092·7191	·75	124·8786	1240·9810
·375	117·4173	1097·1179	·8	125·0356	1244·1210

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·875	125·2713	1248·7982	·25	132·7326	1401·9880
·9	125·3498	1250·3646	·3	132·8896	1405·3083
40inches	125·6640	1256·6400	·375	133·1253	1410·2961
·1	125·9781	1262·9310	·4	133·2038	1411·9607
·125	126·0567	1264·5062	·5	133·5180	1418·6287
·2	126·2929	1269·2388	·6	133·8321	1425·3125
·25	126·4494	1272·3970	·625	133·9107	1426·9859
·3	126·6064	1275·5602	·7	134·1463	1432·0119
·375	126·8421	1280·3124	·75	134·3034	1435·3675
·4	126·9206	1281·8984	·8	134·4604	1438·7271
·5	127·2348	1288·2523	·875	134·6961	1443·7738
·6	127·5489	1294·6219	·9	134·7746	1445·4580
·625	127·6275	1296·2168	43inches	135·0888	1452·2046
·7	127·8631	1301·0071	·1	135·4129	1458·9668
·75	128·0202	1304·2057	·125	135·4815	1460·6599
·8	128·1772	1307·4082	·2	135·7179	1465·7448
·875	128·4129	1312·2193	·25	135·8742	1469·1397
·9	128·4914	1313·8249	·3	136·0332	1472·5385
41inches	128·8056	1320·2574	·375	136·2669	1477·6342
·1	129·1197	1326·7055	·4	136·3454	1479·3480
·125	129·1983	1328·3200	·5	136·6596	1486·1731
·2	129·4323	1333·1693	·6	136·9737	1493·0139
·25	129·5910	1336·4071	·625	137·0523	1494·7266
·3	129·7480	1339·6489	·7	137·2879	1499·8705
·375	129·9837	1344·5189	·75	137·4450	1503·3046
·4	130·0622	1346·1441	·8	137·6020	1506·7427
·5	130·3764	1352·6551	·875	137·8377	1511·9072
·6	130·6905	1359·1818	·9	137·9162	1513·6287
·625	130·7691	1360·8159	44inches	138·2304	1520·5344
·7	131·0047	1365·7242	·1	138·5445	1527·4537
·75	131·1618	1369·0012	·125	138·6231	1529·1860
·8	131·3188	1372·2822	·2	138·8587	1534·3888
·875	131·5545	1377·2111	·25	139·0158	1537·8622
·9	131·6320	1378·8560	·3	139·1728	1541·3396
42inches	131·9472	1385·4456	·375	139·4085	1546·5530
·1	132·2613	1392·0508	·4	139·4870	1548·3061
·125	132·3399	1393·7045	·5	139·8012	1555·2883
·2	132·5755	1398·6717	·6	140·1153	1562·2862

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·625	140·1939	1564·0382	47inches	147·6552	1734·9486
·7	140·4295	1569·2998	·1	147·9693	1742·3392
·75	140·5866	1572·8125	·125	148·0479	1744·1893
·8	140·7436	1576·3292	·2	148·2835	1749·7455
·875	140·9793	1581·6115	·25	148·0406	1753·4545
·9	141·0578	1583·3742	·3	148·5976	1757·1675
45inches	141·3720	1590·4350	·375	148·8333	1762·7344
·1	141·6861	1597·5114	·4	148·9118	1764·6045
·125	141·7647	1599·2830	·5	149·2260	1772·0587
·2	142·0003	1604·6036	·6	149·5361	1779·8279
·25	142·1574	1608·1555	·625	149·6187	1781·3976
·3	142·3144	1611·7114	·7	149·8543	1787·0127
·375	142·5501	1617·0427	·75	150·0114	1790·7610
·4	142·6286	1618·8350	·8	150·1684	1794·5133
·5	142·9428	1625·9743	·875	150·4041	1800·1490
·6	143·2569	1633·1293	·9	150·4826	1802·0296
·625	143·3355	1634·9205	48inches	150·7968	1809·5616
·7	143·5711	1640·3020	·1	151·1109	1817·1092
·75	143·7282	1643·8912	·125	151·1896	1818·9986
·8	143·8852	1647·4864	·2	151·4251	1824·6726
·875	144·1209	1652·8865	·25	151·5822	1828·4602
·9	144·1994	1654·6885	·3	151·7392	1832·2518
46inches	144·5136	1661·9064	·375	151·9749	1837·9364
·1	144·8277	1669·1399	·4	152·0534	1839·8466
·125	144·9063	1670·9507	·5	152·3676	1847·4571
·2	145·1419	1676·3891	·6	152·6817	1855·0833
·25	145·2990	1680·0196	·625	152·7603	1856·9924
·3	145·4560	1683·6541	·7	152·9559	1862·7253
·375	145·6917	1689·1031	·75	153·1530	1868·5521
·4	145·7712	1690·9347	·8	153·3100	1870·3829
·5	146·0844	1698·2311	·875	153·5457	1876·1365
·6	146·3985	1705·5432	·9	153·6242	1878·0563
·625	146·4771	1707·3737	49inches	153·9384	1885·7454
·7	146·7127	1712·8710	·1	154·2525	1893·4501
·75	146·8698	1716·5407	·125	154·3311	1895·3788
·8	147·0628	1720·2144	·2	154·5667	1901·1706
·875	147·2625	1725·7324	·25	154·7238	1905·0367
·9	147·3410	1727·5736	·3	154·8808	1908·9068

Table of the Circumferences, &c.—Continued.

Diameter.	Circum.	Area.	Diameter.	Circum.	Area.
·375	155·1165	1914·7093	·7	156·1375	1940·0006
·4	155·1950	1916·6587	·75	156·2946	1943·9140
·5	155·5092	1924·4263	·8	156·4516	1947·8234
·6	155·8233	1932·2096	·875	156·6873	1953·6947
·625	155·9019	1934·1579	·9	156·7558	1955·6538

Table of Squares, Cubes, Square and Cube Roots of Numbers.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
1	1	1	1·0000000	1·0000000
8	4	2	1·4142136	1·2599210
27	9	3	1·7320508	1·4422496
64	16	4	2·0000000	1·5874011
125	25	5	2·2360680	1·7099759
216	36	6	2·4494897	1·8171216
343	49	7	2·6457513	1·9129312
512	64	8	2·8284271	2·0000000
729	81	9	3·0000000	2·0800837
1000	100	10	3·1622777	2·1544347
1331	121	11	3·3166248	2·2239801
1728	144	12	3·4641016	2·2894286
2197	169	13	3·6055513	2·3513347
2744	196	14	3·7416574	2·4101422
3375	225	15	3·8729833	2·4262121
4096	256	16	4·0000000	2·5198421
4913	289	17	4·1231056	2·6712816
5832	324	18	4·2426407	2·6207417
6859	361	19	4·3588989	2·6684016
8000	400	20	4·4721360	2·7144177
9261	441	21	4·5825757	2·7589243
10648	484	22	4·6904158	2·8020393
12167	529	23	4·7958315	2·8438670
13824	576	24	4·8989795	2·8844991
15625	625	25	5·0000000	2·9240177
17576	676	26	5·0990195	2·9624960
19683	729	27	5·1961524	3·0000000
21952	784	28	5·2915026	3·0365889
24389	841	29	5·3851648	3·0723168
27011	900	30	5·4772256	3·1072325
29791	961	31	5·5677644	3·1413806
32768	1024	32	5·6568542	3·1748021
35937	1089	33	5·7445626	3·2075343
39304	1156	34	5·8309519	3·2396118

Table of Squares, Cubes, &c.—Continued.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
42875	1225	35	5·9164798	3·2710663
46656	1296	36	6·0000000	3·3019272
50653	1369	37	6·0827625	3·3322218
54872	1444	38	6·1644140	3·3619754
59319	1521	39	6·2449980	3·3912114
64000	1600	40	6·3245553	3·4199519
68921	1681	41	6·4031242	3·4482172
74088	1764	42	6·4807407	3·4760266
79507	1849	43	6·5574385	3·5033981
85184	1936	44	6·6332496	3·5303483
91125	2025	45	6·7082039	3·5568933
97336	2116	46	6·7823300	3·5830479
103823	2209	47	6·8556546	3·6088261
110592	2304	48	6·9282032	3·6342411
117649	2401	49	7·0000000	3·6593057
125000	2500	50	7·0710678	3·6840314
132651	2601	51	7·1414284	3·7084298
140608	2704	52	7·2111026	3·7325111
148877	2809	53	7·2801099	3·7562850
157464	2916	54	7·3484692	3·7797631
166375	3025	55	7·4161985	3·8029525
175616	3136	56	7·4833148	3·8258624
185193	3249	57	7·5498344	3·8485011
195012	3364	58	7·6157731	3·8708766
205379	3481	59	7·6811457	3·8929965
216000	3600	60	7·7459667	3·9147632
226981	3721	61	7·8102497	3·9304972
238328	3844	62	7·8740079	3·9578915
250047	3969	63	7·9372539	3·9790571
262144	4096	64	8·0000000	4·0000000
274625	4225	65	8·0622577	4·0207256
287496	4356	66	8·1240384	4·0412401
300763	4489	67	8·1853528	4·0615480
314432	4624	68	8·2462113	4·0816551

Table of Squares, Cubes, &c.—Continued.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
328509	4761	69	8·3066239	4·1015661
343000	4900	70	8·3666003	4·1212853
357911	5041	71	8·4261498	4·1408178
373248	5184	72	8·4852814	4·1601676
389017	5329	73	8·5440037	4·1793390
405224	5476	74	8·6023253	4·1983364
421875	5625	75	8·6602540	4·2171633
438976	5776	76	8·7177979	4·2358286
456533	5929	77	8·7749644	4·2543210
474552	6084	78	8·8317609	4·2726586
493039	6241	79	8·8881944	4·2908404
512000	6400	80	8·9442799	4·3088695
531441	6561	81	9·0000000	4·3267487
551368	6724	82	9·0553851	4·3444815
571787	6889	83	9·1104336	4·3620707
592704	7056	84	9·1631514	4·3795191
614125	7225	85	9·2195445	4·3968296
636056	7396	86	9·2736185	4·4140049
658503	7569	87	9·3273791	4·4310476
681472	7744	88	9·3808315	4·4470692
704969	7921	89	9·4339811	4·4647451
729000	8100	90	9·4868330	4·4814047
753571	8281	91	9·5393920	4·4979414
778688	8464	92	9·5916630	4·5143574
804357	8649	93	9·6436508	4·5306549
830584	8836	94	9·6953597	4·5468359
857374	9025	95	9·7467943	4·5629026
884736	9216	96	9·7979590	4·5788570
912073	9409	97	9·8488578	4·5943009
949912	9604	98	9·8994949	4·6104363
970299	9801	99	9·9498744	4·6260650
1000000	10000	100	10·0000000	4·6415888
1030301	10201	101	10·0498756	4·6570095
1061228	10404	102	10·0995049	4·6723287

Table of Squares, Cubes, &c.—Continued.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
1092727	10609	103	10·1488916	4·6875482
1124864	10816	104	10·1980390	4·7026694
1157625	11025	105	10·2469508	4·7176940
1191016	11236	106	10·2956301	4·7326235
1225043	11449	107	10·3440804	4·7474594
1259712	11664	108	10·3923048	4·7622032
1295029	11881	109	10·4403065	4·7768562
1331000	12100	110	10·4880885	4·7914199
1367631	12321	111	10·5356538	4·8058995
1404928	12524	112	10·5830052	4·8202845
1442897	12769	113	10·6301458	4·8343881
1481344	12996	114	10·6770783	4·8488076
1520875	13225	115	10·7238053	4·8629442
1560896	13456	116	10·7703296	4·8769900
1601613	13689	117	10·8166538	4·8909732
1643032	13924	118	10·8627805	4·9048681
1685159	14161	119	10·9087121	4·9186847
1728000	14400	120	10·9544512	4·9324242
1771561	14641	121	11·0000000	4·9460874
1815848	14834	122	11·0453610	4·9596757
1860867	15129	123	11·0905365	4·9731898
1906624	15376	124	11·1355287	4·9866310
1953125	15625	125	11·1803399	5·0000000
2000376	15876	126	11·2249722	5·0132979
2048383	16129	127	11·2694277	5·0265257
2097152	16384	128	11·3137085	5·0396842
2146689	16641	129	11·3578167	5·0527743
2197000	16900	130	11·4017543	5·0657970
2248091	17161	131	11·4455231	5·0787531
2299968	17424	132	11·4891253	5·0916434
2352637	17689	133	11·5325626	5·1044687
2408104	17956	134	11·5758369	5·1172259
2460375	18225	135	11·6189500	5·1299278
2515456	18496	136	11·6619038	5·1425632

Table of Squares, Cubes, &c.—Continued.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
2571353	18769	137	11·7046999	5·1550367
2628072	19044	138	11·7473444	5·1676493
2685619	19321	139	11·7898261	5·1801015
2744000	19600	140	11·8321596	5·1924941
2803221	19881	141	11·8743421	5·2048279
2863288	20164	142	11·9163753	5·2171034
2924207	20449	143	11·9582607	5·2293315
2985984	20736	144	12·0000000	5·2414828
3048625	21025	145	12·0415946	5·2535879
3112136	21316	146	12·0830460	5·2656374
3176523	21609	147	12·1243557	5·2776321
3241792	21904	148	12·1655251	5·2895725
3307949	22211	149	12·2065556	5·3014592
3375000	22500	150	12·2474487	5·3132928
3442951	22801	151	12·2882057	5·3250740
3511008	23104	152	12·3288280	5·3368033
3581577	23409	153	12·3693169	5·3484812
3652264	23716	154	12·4096736	5·3601084
3723875	24025	155	12·4498996	5·3716854
3796416	24336	156	12·4899960	5·3832126
3869893	24649	157	12·5299641	5·3946907
3944312	24964	158	12·5698051	5·4061202
4019679	25281	159	12·6095202	5·4176015
4096000	25600	160	12·6491106	5·4258352
4173281	25921	161	12·6885775	5·4401218
4251528	26244	162	12·7279221	5·4513618
4330747	26569	163	12·7671453	5·4625556
4410944	26896	164	12·8062485	5·4737037
4492125	27225	165	12·8432326	5·4848066
4574296	27556	166	12·8840987	5·4958647
4657463	27889	167	12·9228480	5·5068784
4741632	28224	168	12·9614814	5·5178484
4826809	28561	169	13·0000000	5·5287748
4913000	28900	170	13·0384048	5·5396583

Table of Squares, Cubes, &c.—Continued.

Cubes.	Squares.	Number.	Square Roots.	Cube Roots.
5000211	29241	171	13·0766968	5·5504990
5088448	29584	172	13·1148770	5·5612578
5177717	29929	173	13·1529464	5·5720546
5268024	30276	174	13·1909060	5·5827702
5359375	30625	175	13·2287566	5·5934447
5451776	30976	176	13·2664992	5·6040787
5545233	31329	177	13·3041347	5·6146724
5639752	31684	178	13·3416641	5·6252263
5735339	32041	179	13·3790882	5·6357408
5832000	32400	180	13·4164079	5·6462162
5929741	32761	181	13·4536240	5·6566528
6028568	33124	182	13·4907376	5·6670511
6128487	33489	183	13·5277493	5·6774114
6229504	33856	184	13·5646600	5·6877340
6331625	34225	185	13·6014705	5·6980192
6434856	34596	186	13·6381817	5·7082675
6539203	34969	187	13·6747943	5·7184791
6644672	35344	188	13·7113092	5·7286543
6751260	35721	189	13·7477271	5·7387936
6859000	36100	190	13·7840488	5·7488971
6967871	36481	191	13·8202750	5·7589652
7077888	36864	192	13·8564065	5·7689982
7189517	37249	193	13·8924400	5·7789966
7301384	37636	194	13·9283883	5·7889604
7414875	38025	195	13·9642400	5·7988900
7529536	38416	196	14·0000000	5·8087857
7645373	38809	197	14·0356688	5·8186479
7762392	39204	198	14·0712473	5·8284867
7880599	39601	199	14·1067360	5·8382725
8000000	40000	200	14·1421356	5·8480355

Table of Hyperbolic Logarithms.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
1·01	·0099503	1·40	·3364722	1·79	·5822156
1·02	·0198026	1·41	·3435897	1·80	·5877866
1·03	·0295588	1·42	·3506568	1·81	·5933268
1·04	·0392207	1·43	·3576744	1·82	·5988365
1·05	·0487902	1·44	·3646431	1·83	·6043159
1·06	·0582689	1·45	·3715635	1·84	·6097655
1·07	·0676586	1·46	·3784364	1·85	·6151856
1·08	·0769610	1·47	·3852624	1·86	·6205764
1·09	·0861777	1·48	·3920420	1·87	·6259384
1·10	·0953102	1·49	·3987761	1·88	·6312717
1·11	·1043600	1·50	·4054651	1·89	·6365768
1·12	·1133287	1·51	·4121096	1·90	·6418538
1·13	·1222176	1·52	·4187103	1·91	·6471032
1·14	·1310283	1·53	·4252677	1·92	·6523251
1·15	·1397619	1·54	·4317824	1·93	·6575200
1·16	·1484200	1·55	·4382549	1·94	·6626879
1·17	·1570037	1·56	·4446858	1·95	·6678293
1·18	·1655144	1·57	·4510756	1·96	·6729444
1·19	·1739533	1·58	·4574248	1·97	·6780335
1·20	·1823215	1·59	·4637340	1·98	·6830968
1·21	·1962030	1·60	·4700036	1·99	·6881346
1·22	·1988508	1·61	·4762341	2·00	·6931472
1·23	·2070141	1·62	·4824261	2·01	·6981347
1·24	·2151113	1·63	·4885800	2·02	·7030974
1·25	·2231435	1·64	·4946962	2·03	·7080357
1·26	·2341117	1·65	·5007752	2·04	·7129497
1·27	·2390169	1·66	·5068175	2·05	·7178397
1·28	·2468600	1·67	·5128236	2·06	·7227059
1·29	·2546422	1·68	·5187937	2·07	·7275485
1·30	·2623642	1·69	·5247285	2·08	·7323678
1·31	·2700271	1·70	·5306282	2·09	·7316470
1·32	·2776317	1·71	·5364933	2·10	·7419378
1·33	·2851789	1·72	·5423242	2·11	·7466879
1·34	·2926696	1·73	·5481214	2·12	·7514160
1·35	·3001045	1.74	·5538851	2·13	·7561219
1·36	·3074846	1·75	·5596157	2·14	·7608058
1·37	·3148107	1·76	·5653138	2·15	·7654678
1·38	·3220834	1·77	·5709795	2·16	·7701082
1·39	·3293037	1·78	·5766133	2·17	·7747271

Table of Hyperbolic Logarithms—Continued.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
2·18	·7793248	2·57	·9439058	2·96	1·0851892
2·19	·7839015	2·58	·9477893	2·97	1·0885619
2·20	·7884573	2·59	·9516578	2·98	1·0919233
2·21	·7929025	2·60	·9555114	2·99	1·0952733
2·22	·7975071	2·61	·9593602	3·00	1·0986123
2·23	·8021015	2·62	·9631743	3·01	1·1019400
2·24	·8064758	2·63	·9669838	3·02	1·1052568
2·25	·8109302	2·64	·9707789	3·03	1·1085626
2·26	·8153648	2·65	·9745596	3·04	1·1118575
2·27	·8197798	2·66	·9783261	3·05	1·1511415
2·28	·8241754	2·67	·9820784	3·06	1·1184149
2·29	·8285518	2·68	·9858167	3·07	1·1216775
2·30	·8329091	2·69	·9895411	3·08	1·1249295
2·31	·8372475	2·70	·9932517	3·09	1·1281710
2·32	·8415671	2·71	·9969486	3·10	1·1314021
2·33	·8458682	2·72	1·0006318	3·11	1·1346227
2·34	·8501509	2·73	1·0043015	3·12	1·1378330
2·35	·8544153	2·74	1·0079579	3·13	1·1410330
2·36	·8586616	2·75	1·0116008	3·14	1·1442227
2·37	·8628899	2·76	1·0152306	3·15	1·1474024
2·38	·8671004	2·77	1·0188473	3·16	1·1505720
2·39	·8712933	2·78	1·0224509	3·17	1·1537315
2·40	·8754687	2·79	1·0260415	3·18	1·1568811
2·41	·8796267	2·80	1·0296194	3·19	1·1600209
2·42	·8837675	2·81	1·0331844	3·20	1·1631508
2·43	·8878912	2·82	1·0367868	3·21	1·1662709
2·44	·8919980	2·83	1·0402766	3·22	1·1693813
2·45	·8960880	2·84	1·0438040	3·23	1·1724821
2·46	·9001613	2·85	1·0473189	3·24	1·1755735
2·47	·9042181	2·86	1·0508216	3·25	1·1786549
2·48	·9082585	2·87	1·0543120	3·26	1·1817271
2·49	·9122826	2·88	1·0577902	3·27	1·1847899
2·50	·9162907	2·89	1·0612564	3·28	1·1878434
2·51	·9202827	2·90	1·0647107	3·29	1·1908875
2·52	·9242589	2·91	1·0681530	3·30	1·1939224
2·53	·9282193	2·92	1·0715836	3·31	1·1969481
2·54	·9321640	2·93	1·0750024	3·32	1·1999647
2·55	·9360933	2·94	1·0784095	3·33	1·2029722
2·56	·9400072	2·95	1·0818051	3·34	1·2059707

Table of Hyperbolic Logarithms—Continued.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
3·35	1·2089603	3·74	1·3190856	4·13	1·4182774
3·36	1·2119409	3·75	1·3217558	4·14	1·4206957
3·37	1·2149127	3·76	1·3244189	4·15	1·4231083
3·38	1·2178757	3·77	1·3271749	4·16	1·4255150
3·39	1·2208299	3·78	1·3297240	4·17	1·4279160
3·40	1·2237754	3·79	1·3323660	4·18	1·4323112
3·41	1·2267122	3·80	1·3350010	4·19	1·4327007
3·42	1·2296405	3·81	1·3376291	4·20	1·4350845
3·43	1·2325605	3·82	1·3402504	4·21	1·4374626
3·44	1·2354714	3·83	1·3428648	4·22	1·4398351
3·45	1·2387420	3·84	1·3454723	4·23	1·4422020
3·46	1·2412685	3·85	1·3480731	4·24	1·4445632
3·47	1·2441545	3·86	1·3506671	4·25	1·4469189
3·48	1·2470322	3·87	1·3532544	4·26	1·4492691
3·49	1·2499017	3·88	1·3558351	4·27	1·4516138
3·50	1·2527629	3·89	1·3584091	4·28	1·4539530
3·51	1·2556160	3·90	1·3609765	4·29	1·4562867
3·52	1·2584609	3·91	1·3635373	4·30	1·4586149
3·53	1·2612978	3·92	1·3660916	4·31	1·4609379
3·54	1·2641266	3·93	1·3686394	4·32	1·4632553
3·55	1·2669475	3·94	1·3711807	4·33	1·4655635
3·56	1·2697605	3·95	1·3737156	4·34	1·4678743
3·57	1·2725655	3·96	1·3726440	4·35	1·4701758
3·58	1·2753627	3·97	1·3787661	4·36	1·4724720
3·59	1·2781521	3·98	1·3812818	4·37	1·4747630
3·60	1·2809338	3·99	1·3837912	4·38	1·4778487
3·61	1·2837077	4·00	1·3862943	4·39	1·4793292
3·62	1·2864740	4·01	1·3887912	4·40	1·4816045
3·63	1·2892326	4·02	1·3912818	4·41	1·4838746
3·64	1·2919836	4·03	1·3937663	4·42	1·4838746
3·65	1·2947271	4·04	1·3962446	4·43	1·4883995
3·66	1·2974631	4·05	1·3987168	4·44	1·4906543
3·67	1·3001916	4·06	1·4011829	4·45	1·4929040
3·68	1·3029127	4·07	1·4036429	4·46	1·4914870
3·69	1·3056264	4·08	1·4060969	4·47	1·4973883
3·70	1·3083328	4·09	1·4085449	4·48	1·4996230
3·71	1·3110318	4·10	1·4109869	4·49	1·5018527
3·72	1·3137236	4·11	1·4134230	4·50	1·5040774
3·78	1·3164082	4·12	1·4158531	4·51	1·5062971

Table of Hyperbolic Logarithms—Continued.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
4·52	1·5085119	4·91	1·5912739	5·30	1·6677068
4·53	1·5107219	4·92	1·5933085	5·31	1·6695918
4·54	1·5129269	4·93	1·5953389	5·32	1·6714733
4·55	1·5151272	4·94	1·5973653	5·33	1·6733512
4·56	1·5173226	4·95	1·5993875	5·34	1·6752256
4·57	1·5195132	4·96	1·6014057	5·35	1·6770965
4·58	1·5216990	4·97	1·6034198	5·36	1·6789639
4·59	1·5238800	4·98	1·6054298	5·37	1·6808278
4·60	1·5260563	4·99	1·6074358	5·38	1·6826882
4·61	1·5282278	5·00	1·6094379	5·39	1·6845453
4·62	1·5303947	5·01	1·6114359	5·40	1·6863989
4·63	1·5325568	5·02	1·6134300	5·41	1·6882491
4·64	1·5347143	5·03	1·6154200	5·42	1·6900958
4·65	1·5368672	5·04	1·6174060	5·43	1·6919391
4·66	1·5390154	5·05	1·6193882	5·44	1·6937790
4·67	1·5411590	5·06	1·6213664	5·45	1·6956155
4·68	1·5432981	5·07	1·6233408	5·46	1·6974487
4·69	1·5454325	5·08	1·6253112	5·47	1·6992786
4·70	1·5475625	5·09	1·6272778	5·48	1·7011051
4·71	1·5496879	5·10	1·6292405	5·49	1·7029282
4·72	1·5518087	5·11	1·6311994	5·50	1·7047481
4·73	1·5539252	5·12	1·6331544	5·51	1·7065646
4·74	1·5560371	5·13	1·6351056	5·52	1·7083778
4·75	1·5581446	5·14	1·6370530	5·53	1·7101878
4·76	1·5602476	5·15	1·6389967	5·54	1·7119944
4·77	1·5623462	5·16	1·6409365	5·55	1·7137979
4·78	1·5644405	5·17	1·6428726	5·56	1·7155981
4·79	1·5665304	5·18	1·6448050	5·57	1·7173950
4·80	1·5686159	5·19	1·6463336	5·58	1·7191887
4·81	1·5706971	5·20	1·6486586	5·59	1·7209792
4·82	1·5727739	5·21	1·6505798	5·60	1·7227666
4·83	1·5748464	5·22	1·6524974	5·61	1·7245507
4·84	1·5769147	5·23	1·6544112	5·62	1·7263316
4·85	1·5789787	5·24	1·6563214	5·63	1·7281004
4·86	1·5810384	5·25	1·6582280	5·64	1·7298840
4·87	1·5830939	5·26	1·6601310	5·65	1·7316555
4·88	1·5851452	5·27	1·6620303	5·66	1·7334238
4·89	1·5870923	5·28	1·6639260	5·67	1·7351891
4·90	1·5892352	5·29	1·6658182	5·68	1·7369512

Table of Hyperbolic Logarithms—Continued.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
5·69	1·7387102	5·93	1·7800242	6·17	1·8196988
5·70	1·7404661	5·94	1·7817091	6·18	1·8213182
5·71	1·7422189	5·95	1·7833112	6·19	1·8229351
5·72	1·7439687	5·96	1·7850704	6·20	1·8245103
5·73	1·7457155	5·97	1·7867469	6·21	1·8261608
5·74	1·7474591	5·98	1·7884205	6·22	1·8277639
5·75	1·7491998	5·99	1·7900914	6·23	1·8293763
5·76	1·7509374	6·00	1·7917594	6·24	1·8309801
5·77	1·7526720	6·01	1·7934247	6·25	1·8325814
5·78	1·7544036	6·02	1·7950872	6·26	1·8341801
5·79	1·7561323	6·03	1·7967470	6·27	1·8357763
5·80	1·7578579	6·04	1·7984040	6·28	1·8373699
5·81	1·7595805	6·05	1·8000582	6·29	1·8389610
5·82	1·7613002	6·06	1·8017098	6·30	1·8405496
5·83	1·7630170	6·07	1·8033586	6·31	1·8421356
5·84	1·7647380	6·08	1·8050047	6·32	1·8437191
5·85	1·7664416	6·09	1·8066481	6·33	1·8453002
5·86	1·7681496	6·10	1·8082887	6·34	1·8468787
5·87	1·7698546	6·11	1·8099267	6·35	1·8484547
5·88	1·7715567	6·12	1·8115621	6·36	1·8500283
5·89	1·7732559	6·13	1·8131947	6·37	1·8515994
5·90	1·7749523	6·14	1·8148247	6·38	1·8531680
5·91	1·7766458	6·15	1·8164520	6·39	1·8547342
5·92	1·7783364	6·16	1·8180767	6·40	1·8562979

Table of Natural Sines, Co-sines, Tangents, Co-tangents, Secants and Co-secants to every degree of the Quadrant.

Deg.	Sines.	Co-sines.	Tangents	Co-tangents.	Secants.	Co-secants	Deg.
0	·00000	1·00000	·00000	Infinite	1·00000	Infinite	90
1	·01745	·99985	·01746	57·2900	1·00015	57·2987	89
2	·03490	·99939	·03492	28·6363	1·00061	28·6537	88
3	·05234	·99863	·05241	19·0811	1·00137	19·1073	87
4	·06976	·99756	·06993	14·3007	1·00244	14·3356	86
5	·08716	·99619	·08749	11·4301	1·00382	11·4737	85
6	·10453	·99452	·10510	9·51236	1·00551	9·56677	84
7	·12187	·99255	·12278	8·14435	1·00751	8·20551	83
8	·13917	·99027	·14054	7·11537	1·00983	7·18530	82
9	·15643	·98769	·15836	6·31375	1·01246	6·39245	81
10	·17365	·98481	·17633	5·67128	1·01543	5·75877	80
11	·19081	·98163	·19438	5·14455	1·01872	5·24084	79
12	·20791	·97815	·21256	4·70463	1·02234	4·80973	78
13	·22495	·97437	·23087	4·33148	1·02630	4·44541	77
14	·24192	·97030	·24933	4·01078	1·03061	4·13356	76
15	·25882	·96593	·26795	3·73205	1·03588	3·86370	75
16	·27564	·96126	·28675	3·48741	1·04030	3·62796	74
17	·29237	·95630	·30573	3·27085	1·04589	3·42030	73
18	·30902	·95106	·32492	3·07768	1·05146	3·23607	72
19	·32557	·94552	·34433	2·90421	1·05762	3·07155	71
20	·34202	·93969	·36397	2·74748	1·06418	2·92380	70
21	·35837	·93358	·38386	2·60509	1·07114	2·79043	69
22	·37461	·92718	·40403	2·47509	1·07853	2·66947	68
23	·39073	·92060	·42447	2·35585	1·08636	2·55930	67
24	·40674	·91355	·44523	2·24004	1·09464	2·45859	66
25	·42262	·90631	·46631	2·14451	1·10338	2·36620	65
26	·43837	·89879	·48773	2·05030	1·11260	2·28117	64
27	·45399	·89101	·50952	1·96261	1·12233	2·20869	63
28	·46947	·88295	·53171	1·88073	1·13257	2·13005	62
29	·48481	·87462	·55431	1·80405	1·14335	2·06266	61
30	·50000	·86603	·57735	1·73205	1·15470	2·00000	60
31	·51504	·85717	·60086	1·66428	1·16663	1·94160	59
32	·52992	·84805	·62487	1·60033	1·17918	1·88708	58
33	·54464	·83867	·64941	1·53986	1·19236	1·83608	57
34	·55919	·82904	·67451	1·48256	1·20622	1·78829	56
35	·57358	·81915	·70021	1·42815	1·22077	1·74345	55
36	·58778	·80902	·72654	1·37638	1·23607	1·70130	54
37	·60181	·79863	·75355	1·32704	1·25214	1·66164	53
38	·61566	·78801	·78129	1·27994	1·26902	1·62427	52
39	·62932	·77715	·80978	1·23490	1·28676	1·58902	51
40	·64279	·76604	·83910	1·19175	1·30541	1·55572	50
41	·65606	·75471	·86929	1·15037	1·32611	1·52425	49
42	·66993	·74314	·90040	1·11061	1·34561	1·49448	48
43	·68200	·73135	·93251	1·07237	1·36706	1·46628	47
44	·69466	·71934	·96569	1·03553	1·39012	1·43956	46
45	·70711	·70711	1·00000	1·00000	1·41421	1·41421	45

Table of the Expansion of Air by Heat, that at 32° Fahrenheit being 1·000.

Fah.	Volume.	Fah.	Volume.	Fah.	Volume.
35° ...	1·007	85° ...	1·121	170° ...	1·295
40 ...	1·021	90 ...	1·132	180 ...	1·315
45 ...	1·032	95 ...	1·142	190 ...	1·334
50 ...	1·043	100 ...	1·152	200 ...	1·864
55 ...	1·055	110 ...	1·173	210 ...	1·372
60 ...	1·066	120 ...	1·194	212 ...	1·376
65 ...	1·077	130 ...	1·215	302 ...	1·558
70 ...	1·089	140 ...	1·235	392 ...	1·739
75 ...	1·099	150 ...	1·255	482 ...	1·919
80 ...	1·110	160 ...	1·275	572 ...	2·098

NOTE.—One hundred parts of pure air by weight contain 75·55 parts of nitrogen, 23·32 parts oxygen, and 1·3 carbonic acid, and watery vapour.

The weight or pressure of the atmosphere equal a column of water 34 feet in height, or a column of mercury 30 inches in height, or 14·7 pounds per square inch at a mean temperature.

The resistance of air increases as the square of the velocity, and the resistance per square foot as the velocity multiplied by ·002288.

Table of the Relative Indications of Barometer and Thermometer at the boiling points of Fresh Water.

When the Barometer indicates 30 inches, the boiling point is 212° Fah., and 0·589 of barometric pressure corresponds to a difference of 1° Fah.

Columns of Fresh Water in feet equal to columns of Mercury in inches.	Barometer, Height of Mercury in inches.	Thermometer, Degrees of Fahrenheit.
35·07	31	213·57
34·50	30·5	212·79
34·02	30	212·00
33·37	29·5	211·20
32·81	29	210·38
32·22	28·5	209·55
31·84	28	208·69
31·11	27·5	207·84
30·52	27	206·96
	In a vacuum, water boils at	98·00 to 100

To find the height of a mountain by the Barometer.

Rule 1.—Multiply the difference between 82° Fah. and the mean temperature of the air by ·21, and add the product to 87 if the mean temperature be above 32°, but subtract it if below.

Rule 2.—Multiply the sum or difference as found above by thirty times the difference between the barometric heights in tenths of inches, and divide the product by the mean of the barometric heights; the quotient is the approximated elevation.

Rule 3.—Multiply the difference between the mercurial temperatures by 2·833 feet, and add the product to the approximated elevation if that of the upper barometer be the greatest, otherwise subtract it; the result will be the corrected elevation in English feet.

Table of Specific Gravities.

Metals.	Weight, water being 1000.	Number of cubic inches in a pound.	Weight of a cubic inch in pounds.
Platina	19500	1·417	·7053
Rare gold	19258	1·435	·6965
Mercury	13560	2·04	·4902
Lead	11352	2·435	·4105
Pure silver	10474	2·638	·3788
Bismuth	9823	2·814	·3552
Copper	8788	3·146	·3178
Brass	7824	3·533	·3036
Iron, cast	7264	3·806	·263
Iron, bar	7700	3·592	·279
Steel	7833	3·530	·2833
Tin	7291	3·790	·2636
Zinc	7190	3·845	·26

Various Bodies.	Weight, water being 1000.	Weight of a cubic foot in pounds.	Number of cubic feet in a ton.
Marble, average	2720	170·0	13
Granite, do.	2651	165·6	13·5
Chalk, British	2781	173·8	12·75
Brick, red, common	2160	135·0	17·5
Brick, fire, Welsh	2408	150·5	14·5
Tallow, average	942	59·0	38·0
Ice, from fresh water	1001	53·0	35·5
Coal, Welsh	1526	95·3	24·7
Coal, Lancashire	1319	82·4	26·0
Coal, Scotch	1300	81·5	27·5
Coal, cannel	1272	79·5	28·0
Coal, Newcastle	1270	79·3	28·2
Coke, dry	755	47·0	47·6

Table of Specific Gravities—Continued.

Timber, Seasoned.	Weight, water being 1000.	Weight of a cubic foot in pounds.	Number of cubic feet in a ton.
English oak	934	58	38·5
African oak	944	59	38·0
Riga oak	872	54	41·5
Beach oak	852	48	45·0
Ash oak	845	52	43·0
Mahogany, Spanish	800	50	45·0
Dantzic oak	756	47	48·0
Riga fir	753	47	48·0
Maple	752	47	47·5
Teak	750	46	48·5
Elm	673	42	53·0
American oak	672	42	53·0
Walnut	671	41·9	53·5
Pitch pine	660	41	54·5
Red pine	657	47	54·5
Poona	640	40	55·0
Mahogany, Honduras	637	40	55·0
Sycamore	604	38	59.0
Lime-tree	600	37	59·5
Cedar	561	35	64·0
Yellow pine	461	28	80·0
Cork	240	15	149·0
Pine, white	426	26	84·2

Table of Specific Gravities—Continued.

Liquids.	Weight, water being 1000.	Weight of an imp. gallon in pounds.
Water from the Dead Sea . . .	1240	12·4
Water from the Mediterranean .	1029	10·3
Water from the Irish Channel .	1028	10·2
Water from the Baltic	1015	10·2
Vinegar	1010	10·1
Turpentine	991	9·8
Linseed oil	940	9·4
Whale oil	923	9·2
Proof spirit	922	9·2
Rape-seed oil	919	9·3
Olive oil	915	9·2
Alcohol, com.	837	8·3

Names of Gases, Atmospheric Air being 1000.	
Carbonic acid gas	1527
Oxygen	1111
Carburetted hydrogen	972
Nitrogen	969
Steam of water at 212°	623
Chlorine	470
Hydrogen	69

Table of the Weight of Bar Iron.

ROUND.					
Diameter in inches.	Length, one foot.		Diameter in inches.	Length, one foot.	
	Weight in pounds.	Weight in pounds.		Weight in pounds.	Weight in pounds.
$\frac{1}{4}$	·164	·0137	$3\frac{1}{8}$	25·620	2·135
$\frac{5}{16}$	·256	·0233	$3\frac{1}{4}$	27·709	2·309
$\frac{3}{8}$	·369	·0307	$3\frac{3}{8}$	29·881	2·490
$\frac{7}{16}$	·503	·0420	$3\frac{1}{2}$	32·170	2·681
$\frac{1}{2}$	·656	·0547	$3\frac{5}{8}$	34·472	2·873
$\frac{9}{16}$	·831	·0692	$3\frac{3}{4}$	36·895	3·075
$\frac{5}{8}$	1·025	·0854	$3\frac{7}{8}$	39·390	3·283
$\frac{11}{16}$	1·241	·1034	4 in.	41·984	3·499
$\frac{3}{4}$	1·476	·1230	$4\frac{1}{8}$	44·637	3·720
$\frac{13}{16}$	1·732	·1443	$4\frac{1}{4}$	47·385	3·949
$\frac{7}{8}$	2·011	·1676	$4\frac{1}{2}$	53·132	4·428
$\frac{15}{16}$	2·306	·1921	$4\frac{3}{4}$	59·187	4·932
1 in.	2·624	·2187	5 in.	65·585	5·465
$1\frac{1}{8}$	3·321	·2767	$5\frac{1}{4}$	72·618	6·051
$1\frac{1}{4}$	4·099	·3146	$5\frac{1}{2}$	79·370	6·614
$1\frac{3}{8}$	4·961	·4134	$5\frac{3}{4}$	86·731	7·227
$1\frac{1}{2}$	5·913	·4927	6 in.	94·610	7·884
$1\frac{5}{8}$	6·928	·5773	$6\frac{1}{4}$	110·84	9·237
$1\frac{3}{4}$	8·043	·6702	7 in.	128·68	10·723
$1\frac{7}{8}$	9·224	·7686	$7\frac{1}{2}$	147·58	12·298
2 in.	10·496	·8747	8 in.	167·94	13·995
$2\frac{1}{8}$	11·846	·9872	$8\frac{1}{2}$	189·54	15·795
$2\frac{1}{4}$	13·283	1·107	9 in.	212·53	17·710
$2\frac{3}{8}$	14·797	1·233	$9\frac{1}{2}$	236·75	19·729
$2\frac{1}{2}$	16·396	1·366	10 in.	262·34	21·861
$2\frac{5}{8}$	18·146	1·512	$10\frac{1}{2}$	290·47	24·206
$2\frac{3}{4}$	19·842	1·653	11 in.	317·48	26·457
$2\frac{7}{8}$	21·684	1·307	$11\frac{1}{2}$	346·93	28·911
3 in.	23·653	1·971	12 in.	378·44	31·537

Table of the Weight of Bar Iron—Continued.

Square.					
Side of square in inches.	Length, one foot.		Side of square in inches.	Length, one foot.	
	Weight in pounds.	Weight in pounds.		Weight in pounds.	Weight in pounds.
$\frac{1}{16}$	·209	·0174	$2\frac{1}{8}$	15·083	1·257
$\frac{1}{8}$	·470	·0391	$2\frac{1}{4}$	16·909	1·409
$\frac{1}{8}$	·835	·0696	$2\frac{3}{8}$	18·840	1·570
$\frac{5}{16}$	1·305	·1087	$2\frac{1}{2}$	20·875	1·739
$\frac{3}{8}$	1·879	·1565	$2\frac{5}{8}$	23·115	1·926
$\frac{7}{16}$	2·558	·2131	$2\frac{3}{4}$	25·259	2·105
1 in.	3·340	·2783	$2\frac{7}{8}$	27·608	2·301
$1\frac{1}{8}$	4·228	·3523	3 in.	30·070	2·506
$1\frac{1}{4}$	5·219	·4349	$3\frac{1}{4}$	35·279	2·940
$1\frac{3}{8}$	6·315	·5262	$3\frac{1}{2}$	40·916	3·409
$1\frac{1}{2}$	7·516	·6263	$3\frac{3}{4}$	46·969	3·914
$1\frac{5}{8}$	8·820	·7350	4 in.	53·440	4·455
$1\frac{3}{4}$	10·229	·8524	$4\frac{1}{2}$	67·637	5·636
$1\frac{7}{8}$	11·743	·9786	5 in.	83·510	6·959
2 in.	13·360	1·113			

Weight of a Lineal Foot of Common Angle Iron, for the construction of Steam Boilers, &c.

Breadth in inches.	Weight in pounds.	Breadth in inches.	Weight in pounds.
3	10·4	2	3·9
$2\frac{3}{4}$	8·3	$1\frac{3}{4}$	3·8
$2\frac{1}{2}$	6·5	$1\frac{1}{2}$	2·7
$2\frac{1}{4}$	5·0		

TABLE OF THE WEIGHT OF FLAT BAR, HOOP, PLATE, AND SHEET IRON.

Weight of a Lineal Foot of Flat Bar and Hoop Iron in pounds.

Thickness in inches.	Breadth in inches.										
	2½	3	2¾	2½	2¼	2	1⅞	1½	1¼	1	¾
⅛	1·47	1·26	1·15	1·05	·094	·084	·073	·063	·052	·042	·031
3-16	2·20	1·89	1·73	1·57	1·41	1·26	1·10	·094	·078	·063	·047
¼	2·94	2·52	2·31	2·10	1·89	1·68	1·47	1·26	1·05	·084	·063
⅜	4·41	3·78	3·46	3·15	2·83	2·52	2·20	1·89	1·57	1·26	·094
½	5·88	5·04	4·62	4·20	3·78	3·36	2·94	2·22	2·10	1·68	1·26
⅝	7·35	6·30	5·77	5·25	4·72	4·20	3·67	3·15	2·62	2·10	1·57
¾	8·82	7·56	6·93	6·30	5·66	5·04	4·41	3·78	3·15	2·52	
⅞	10·29	8·82	8·08	7·35	6·61	5·88	5·14	4.41	3·67	2·94	
1 in.	11·76	10·08	9·24	8·40	7·56	6·72	5·87	5·04	4·20		

Weight of a Square Foot of Plate Iron in pounds.

Thickness in parts of an inch.	⅛	3-16	¼	5-16	⅜	7-16	½	9-16	⅝	11-16	¾
Weight in pounds.	5	7½	10	12½	15	17½	20	22½	25	27½	30

Weight of Square Foot of Sheet Iron in pounds.

Number on wire gauge,	1	2	3	4	5	6	7	8	9	10	11
and weight in pounds.	12·5	12	11	10	9	8	7·5	7	6	5·68	5
Number on wire gauge,	12	13	14	15	16	17	18	19	20	21	22
and weight in pounds.	4·62	4·32	4	3·95	3	2·5	2·18	1·93	1·62	1·5	1·37

Weight of a Square Foot of Sheet and Plate Copper in pounds.

Number on wire gauge,	12	13	14	15	16	17	18	19	20	21	22
and weight in pounds.	5·08	4·34	3·60	3·27	2·90	2·52	2·15	1·97	1·78	1·62	1·45
Thickness in parts of an inch.	5-32	3-16	7-32	¼	9-32	5-16	11-32	⅜	13-32	7-16	½ in.
Weight in pounds.	7·26	8·71	10·16	11·61	13·07	14·52	15·97	17·41	18·87	20·32	23·22

NOTE.—The weight of plate or sheet iron being 1. The weight of brass equals 1·09, and the weight of lead 1·48.

ENGLISH STANDARD MEASURES.

LINEAL MEASURE.

12 inches	=	1 foot.
3 feet	=	1 yard.
1760 yards, or 5280 feet	=	1 statute mile.
7·92 inches	=	1 link.
100 links, or 22 yards	=	1 chain.
80 chains	=	1 statute mile.

SQUARE MEASURE.

144 square inches	=	1 square foot.
9 square feet	=	1 square yard.
4840 square yards	=	1 acre.
62·7264 square inches	=	1 square link.
10000 square links	=	1 square chain.
10 square chains	=	1 acre.

CUBIC MEASURE.

1728 cubic inches	=	1 cubic foot.
27 cubic feet	=	1 cubic yard.

LIQUID MEASURE.

8·665 cubic inches	=	1 gill.
4 gills	=	1 pint.
2 pints	=	1 quart.
4 quarts, or 277·274 cubic inches	=	1 gallon.

CORN MEASURE.

2 gallons	=	1 peck.
4 pecks, or 2218·192 cubic inches	=	1 bushel.
8 bushels	=	1 quarter.
5 quarters	=	1 load.

AVOIRDUPOIS WEIGHT.

27·34375 troy grains	=	1 drachm.
16 drachms	=	1 ounce.
16 ounces	=	1 pound.
28 pounds	=	1 quarter.
4 quarters, or 112 pounds	=	1 cwt.
20 cwts., or 2240 pounds	=	1 ton.

Common Gravity of Fresh Water.

1 cubic inch	=	·03617 pound.
12 cubic inches	=	·434 "
1 cubic foot	=	62·5 pounds.
1·8 cubic feet	=	1 cwt.
35·84 cubic feet	=	1 ton.
1 cylindrical inch	=	·02842 pound.
12 " inches	=	·341 "
1 " foot	=	49·1 pounds.
2·282 " feet	=	1 cwt.
45·64 " feet	=	1 ton.
1 cubic foot	=	6·25 imp. galls.
1 cylindrical foot	=	5 imp. gallons.
11·2 imperial gallons	=	1 cwt.
224 " "	=	1 ton.
1 cubic foot of sea-water	=	64·2 pounds.
34·9 cubic feet of do.	=	1 ton.

Approximate Weights for Practical Purposes.

	Specific gravities.	Weight of a cubic inch in pounds.	Weight of a cylindrical inch in pounds.
Iron, cast . .	7207	·2608	·2048
Iron, bar . .	7700	·2785	·2187
Steel	7833	·2833	·2225
Copper . . .	8878	·3211	·2522
Brass, cast . .	8396	·3037	·2385
Zinc, common .	7028	·2542	·1996
Lead	11352	·4106	·3225
Tin, cast . . .	7291	·2637	·2071

Foreign Lineal Measures compared with the Yard English.

One yard English						English yards.
=	·9143	French metres,	or one metre	=	1·0937	
=	1·5958	Hamburg ells,	or one ell	=	·6210	
=	1·4567	Denmark ells,	or one ell	=	·6865	
=	1·5400	Swedish ells,	or one ell	=	·6493	
=	1·3710	Prussian ells,	or one ell	=	·7298	
=	1·2857	Russian arshines,	or one arshine	=	·7778	
=	1·3521	Turkish pikes,	or one pike	=	·7396	
=	1·1735	Austrian ells,	or one ell	=	·8522	
=	·4327	Neapolitan cannes,	or one canne	=	2·3111	
=	1·5387	Leghorn braccia,	or one braccia	=	·6492	
=	·3657	Genoese cannes,	or one canne	=	2·7345	
=	1·0783	Spanish varas,	or one vara	=	·9274	
=	·8345	Portuguese varas,	or one vara	=	1·1984	

Table showing the Course of Exchange between London and various Foreign Places. (From Tate's "Modern Cambist.")

LONDON RECEIVES FROM OR GIVES TO

Amsterdam	12	8	florins and stivers	for £1	sterling.
Hamburg	13	12	marks and schillings	1	"
Paris	25	50	francs and cents	1	"
Frankfort		150½	batzen	1	"
Vienna	10	2	florins and kreuz	1	"
Genoa	25	35	lire and centisimi	1	"
Berlin	6	25	dollars and silver gros.	1	"
Milan	30	30	lire A. and cent	1	"
Leghorn	30	50	lire Tosc. and cent	1	"

Lisbon	53¼	pence sterling for	one milreis.
Madrid	36¾	"	one dollar of plate.
Gibraltar	48¼	"	one hard dollar.
Naples	39⅝	"	one ducat.
Palermo	119½	"	one onza.
Venice	47	"	six lire Austriache.
St. Petersburg	38¼	"	one silver rouble.
Rio Janeiro	30	"	one milreis.
New York	47½	"	one U. S. dollar.
Calcutta	23	"	one Comp. rupee.

The rates of Rotterdam and Antwerp are similar to those of Amsterdam; Trieste, to that of Vienna; and Cadiz, Bilboa, Barcelona, and Seville, to that of Madrid.

The above list comprises all the places with which exchange dealings are commonly transacted. But it will be observed that the quotations are of two kinds—one where a variable amount of foreign money is given for a certain sum in English, viz. £1; and the other, where England gives an uncertain number of pence for a fixed coin of foreign money. Thus, between London and Paris the rate of exchange is the value which is given for the British pound sterling in a variable sum in francs and cents. The former sum is therefore the fixed price, and the latter the variable or uncertain price. Also between London and Lisbon the rate of exchange is the value in pence sterling which is given for the milreis, and therefore in this rate the sterling money is the variable price. When the fixed price is in the money of the country, that place is said to receive the variable price. When the uncertain price is in that money, it is said to give the variable price. Thus—

London receives from Paris 25 francs 50 cents for £1 sterling.

London gives Lisbon 53¼ pence sterling for one milreis.

Table giving the Distance of Terrestrial Objects at Sea.

Height of the eye in feet.	Distance of the object in miles.	Height of the eye in feet.	Distance of the object in miles.	Height of the eye in feet.	Distance of the object in miles.	Height of the eye in feet.	Distance of the object in miles.
1	1·32	20	5·92	39	8·26	90	12·55
2	1·87	21	6·06	40	8·37	95	12·89
3	2·29	22	6·21	41	8·47	100	13·23
4	2·65	23	6·34	42	8·57	105	13·56
5	2·96	24	6·48	43	8·68	110	13·88
6	3·24	25	6·61	44	8·75	115	14·19
7	3·50	26	6·75	45	8·87	120	14·49
8	3·74	27	6·87	46	8·97	125	14·79
9	3·97	28	7·00	47	9·07	130	15·08
10	4·18	29	7·12	48	9·17	135	15·37
11	4·39	30	7·25	49	9·26	140	15·65
12	4·58	31	7·37	50	9·35	145	15·93
13	4·77	32	7·48	55	9·81	150	16·20
14	4·95	33	7·60	60	10·25	160	16·73
15	5·12	34	7·71	65	10·67	170	17·25
16	5·29	35	7·83	70	11·07	180	17·75
17	5·45	36	7·94	75	11·46	190	18·24
18	5·61	37	8·05	80	11·83	200	18·71
19	5·77	38	8·16	85	12·20		

NOTE.—It is ascertained that sound in a temperature of 62° Fahrenheit travels at the rate of 1125 feet per second, and a diminution of temperature equal to 1° Fahrenheit causes an increased velocity of sound equal to 1·14 feet; hence, suppose the flash of a gun from a ship is seen 33 seconds before the report is heard, the distance will be $1125 \times 33 =$ 37,125 feet, or, 12,375 yards between the gun and where the report is heard.

To compare Degrees of Temperature indicated by different Thermometers.

RULE 1.—Multiply degrees of Centigrade by 9 and divide by 5; or multiply degrees of Reaumur by 9 and divide by 4. Add 32 to the quotient in either case, and the sum is degrees of Fahrenheit.

RULE 2.—From degrees of Fahrenheit subtract 32, multiply the remainder by 5, and divide by 9 for degrees of Centigrade; or multiply by 4 and divide by 9 for degrees of Reaumur.

Tables deduced from Experiments on Iron and Copper Plates for Steam Boilers, by the Franklin Institute, Philadelphia.

Iron boiler plate was found to increase in tenacity as its temperature was raised, until it reached a temperature of 550° above the freezing point, at which point its tenacity began to diminish. The following table exhibits the cohesive strength at different temperatures:—

At	32° to 80°	the tenacity was	= 56,000 lbs., or one-seventh below its maximum.
At	570°	" "	= 66,500 lbs., the maximum.
At	720°	" "	= 55,000 lbs., the same nearly as at 32°.
At	1050°	" "	= 32,000 lbs., nearly one-half of the maximum.
At	1240°	" "	= 22,000 lbs., nearly one-third of the maximum.
At	1317°	" "	= 9,000 lbs., nearly one-seventh of the maximum.

At 3000° iron becomes fluid.

NOTE.—The accidental overheating of a boiler was found to reduce its strength from 65,000 pounds to 45,000 per square inch.

Table showing the Diminution of Strength of Copper Boiler Plates by additions to the temperature, the cohesion at 32° being 32,800 pounds per square inch.

No.	Temperature above 32°.	Diminution of strength.	No.	Temperature above 32°.	Diminution of strength.
1	90°	0·0175	9	660°	0·3425
2	180	0·0540	10	769	0·4398
3	270	0·0926	11	812	0·4944
4	360	0·1513	12	880	0·5581
5	450	0·2046	13	984	0·6691
6	460	0·2133	14	1000	0·6741
7	513	0·2446	15	1200	0·8861
8	529	0·2558	16	1300	1·0000

Table of Experiments on Iron Boiler Plate at high temperatures, the mean maximum tenacity being at 550°=65,000 pounds per square inch.

Temperature observed.	Diminution of tenacity observed.	Temperature observed.	Diminution of tenacity observed.
550°	0·0000	824°	0·2010
570	0·0869	932	0·3324
596	0·0899	947	0·3593
600	0·0964	1030	0·4478
630	0·1047	1111	0·5514
652	0·1155	1155	0·6000
722	0·1436	1159	0·6011
732	0·1491	1187	0·6352
734	0·1535	1237	0·6622
766	0·1589	1245	0·6715
770	0·1627	1317	0·7001

Table specifying the Value of the Moneys of Account of the principal places with which this country has Exchange transactions, taking silver at five shillings per ounce; and specifying also the Par of Exchange with such places on this hypothesis. (Abstracted from Tate's "Modern Cambist.")

The calculations being made at five shillings per ounce, and the Mint price of silver being five shillings and two pence per ounce, allowance must be made for the difference.

Petersburg	100	copecks	=	1	rouble	=	3s.	$1\frac{1}{2}$*d.*,	giving	6 roubles 40 cop.	= £1
Berlin	30	silver groschen	=	1	Prussian dollar	=	2	$10\frac{3}{4}$	"	6 dolls. 27 sil. gros.	= 1
Copenhagen	96	skillings	=	1	Reig. dollar	=	2	$2\frac{1}{3}$	"	9 dolls. 10 skillings	= 1
Hamburg	16	schillings	=	1	mark	=	1	$5\frac{1}{2}$	"	13 marks $10\frac{1}{2}$ sch.	= 1
Amsterdam	100	centimes	=	1	florin	=	1	8	"	11 florins 97 cents.	= 1
Antwerp	100	centimes	=	1	florin	=	1	8	"	11 florins 97 cents.	= 1
Paris	100	centimes	=	1	franc	=	0	$9\frac{1}{2}$	"	25 francs 57 cents.	= 1
Frankfort	$24\frac{1}{2}$	guld. or florins	=	1	mark	=	1	$7\frac{7}{8}$	"	$12\frac{3}{10}$ guilders	= 1
Vienna	60	kreuzers	=	1	florin	=	2	$0\frac{4}{10}$	"	9 florins 50 kreuzers	= 1
Venice	100	centisimi	=	1	lira Austriaca	=	0	$8\frac{1}{3}$	"	29 lire 52 cents.	= 1
Genoa	100	centisimi	=	1	lira Nuova	=	0	$9\frac{1}{2}$	"	15 lire 57 cents.	= 1
Leghorn	100	centisimi	=	1	lira Toscana	=	0	$8\frac{1}{12}$	"	30 lire 69 cents.	= 1
Madrid	8	reals	=	1	dollar of plate	=	3	$1\frac{1}{4}$	"	6 dollars $2\frac{3}{4}$ reals	= 1
Lisbon	1000	reis	=	1	milreis	=	4	8	"	4 milreis 285 reis	= 1
New York	100	cents	=	1	dollar	=	4	2	"	4 dollars 80 cents	= 1
Rio Janeiro	1000	reis	=	1	milreis	=	2	7	"	7 milreis 117 reis	= 1
Havana	100	cents	=	1	dollar	=	4	$6\frac{13}{21}$	"	4 dollars 44 cents	= 1

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